APPENDIX E. STANDARD PLAN: ALLOWABLE BMP OPTIONS

The following section provides descriptions, advantages, limitations, and schematics of allowable best management practices (BMPs) for use under the Critical Area Standard Plan. This section is divided into two main parts:

- Non-Structural BMPs
- Structural BMPs

For the purposes of this Manual, non-structural BMPs are not given a phosphorus removal rate but are used to reduce or erase proposed impervious cover at the site. Use of non-structural BMPs can reduce or eliminate the need for costly structural BMPs.

The second part of this section describes structural BMPs that are outlined within the Maryland Stormwater Design Manual. These BMPs are subject to the performance and design criteria set forth by the 2000 Maryland Stormwater Design Manual, which is available online:
http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp.

NON-STRUCTURAL BMPS

Non-structural BMPs are mainly used within the Critical Area to disconnect impervious cover. These BMPs are organized by several non-structural strategies to reduce the amount of stormwater runoff:

- Strategies to Disconnect Rooftop Runoff
- Strategies to Store Rooftop Runoff
- Strategies to Disconnect Non-Rooftop Runoff
- Approved on a Case-by-Case Basis

The majority of non-structural BMPs do not require numerical sizing to meet drainage needs. However, limited sizing criteria are available for grass channel and filter strip sizing in the Maryland Stormwater Design Manual:
http://www.mde.state.md.us/assets/document/chapter5.pdf

Strategies to Disconnect Rooftop Runoff

Filter Strips

A filter strip is a vegetated area that is intended to treat sheet flow from adjacent impervious areas (Figure E.1). Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants and providing some infiltration to underlying soils. Filter strips are best suited to treat runoff from roads and highways, roof downspouts, very small parking lots, and pervious surfaces.

Advantages

- Ideal as pretreatment to another stormwater treatment practice
- Can be applied in most regions of the state

Limitations

- There is not much monitoring data to suggest that the practice can achieve high pollutant removal
- Require a large amount of space in relation to the impervious area they treat
- If poorly designed, filter strips can cause soil erosion and become a mosquito breeding ground
- Require regular mowing

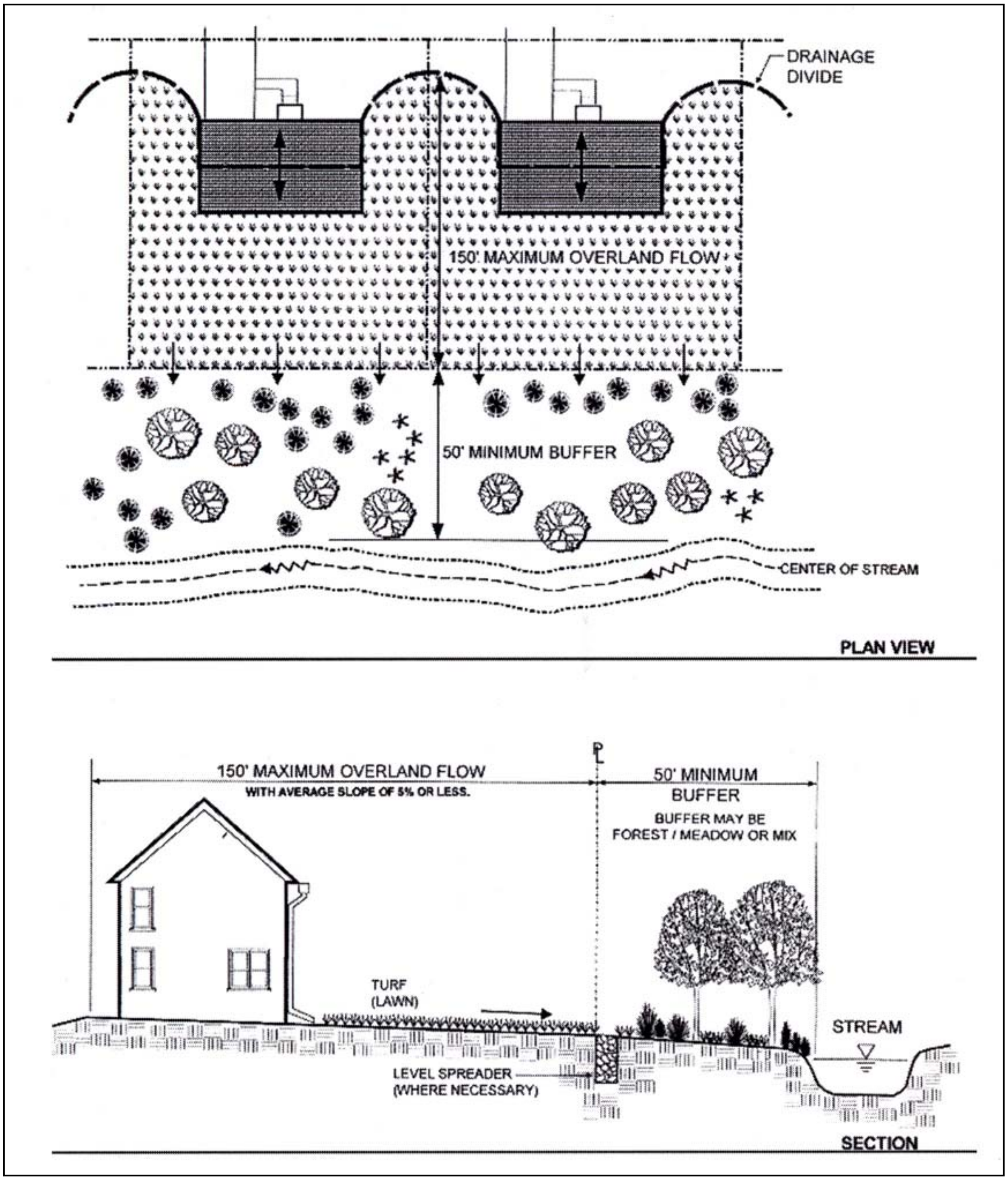

Figure E.1 Schematic of a Filter Strip
(Source: Maryland Stormwater Design Manual, 2000)

Strategies to Store Rooftop Runoff

Vegetated Rooftops

A vegetated rooftop, also called a green rooftop, is a thin layer of soil and vegetation installed on top of a conventional flat or sloped roof (Figure E.2). In the summer, vegetated rooftops retain 70 to 100% of the precipitation that falls on them; in the winter they retain 40 to 50% (Green Roofs for Healthy Cities). Vegetated rooftops can reduce the total annual runoff volume by 50 to 60% (Roofscapes, Inc.). Rooftop vegetation can range from turf and grass to shrubs or even trees, depending on the climate and the load-bearing capacity of the roof. The turf-dominated, or "extensive green roof" is lighter, less expensive, and has limited space for people, while the rooftop garden, or "intensive green roof" is heavier, requires more management/maintenance, and can accommodate people.

Advantages

- Reduce runoff volume and peak flow rate
- Increase property values
- Provide green open space
- Provide habitat
- Conserve space that would otherwise be used for stormwater treatment
- May be best choice for stormwater management in redevelopment projects due to lack of space and pervious cover

Limitations

- May need maintenance in first few years of growing
- May require watering depending on type of vegetation, climate, and season.
- May be difficult to implement on existing structures without providing structural reinforcement
- Professional/contractor installation fees can be expensive
- Local building codes may require mechanical fastening of the drainage and insulation layers
- More difficult to use on pitched roofs

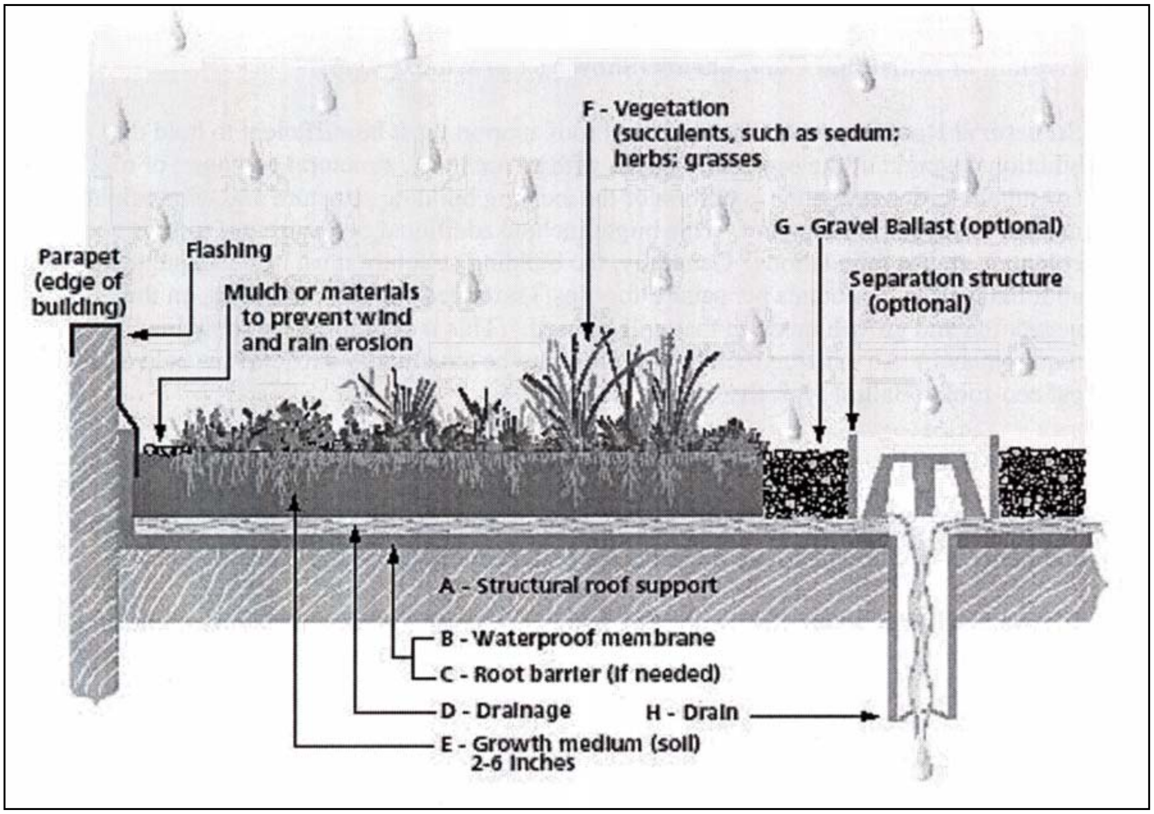

Figure E.2 Schematic of Vegetated Rooftop
(Source: Portland, OR Stormwater Management Manual, 2002)

Strategies to Disconnect Non-Rooftop Runoff

Permeable Pavers

Permeable pavers are permeable surfaces that can replace asphalt and concrete and can be used for driveways (Figure E.3), parking lots and walkways. From a stormwater perspective, this is important because permeable pavers can replace impervious surfaces, creating less stormwater runoff. For the purposes of the 10% Rule, the perviousness of permeable pavers ranges from 10 to 50%, depending on the product. Permeable pavers must be installed to the manufactures specifications. Utilizing the manufacturer's specifications, the applicant should collaborate with the local government to determine exact imperviousness.

Advantages

- Can replace conventional asphalt or concrete in parking lots, driveways, and walkways
- Can abate overall stormwater management costs by reducing or eliminating the need of other stormwater management techniques
- Reduces pavement ponding

Limitations

- Slight to moderate risk of groundwater contamination depending on soil conditions and aquifer susceptibility
- High failure rate potential
- Requires regular maintenance
- No sanding for de-icing permitted
- Only feasible where soil is permeable, there is sufficient depth to bedrock and water table, and there are gentle slopes
- Not suitable for areas with high traffic volume
- More expensive than traditional paving surfaces

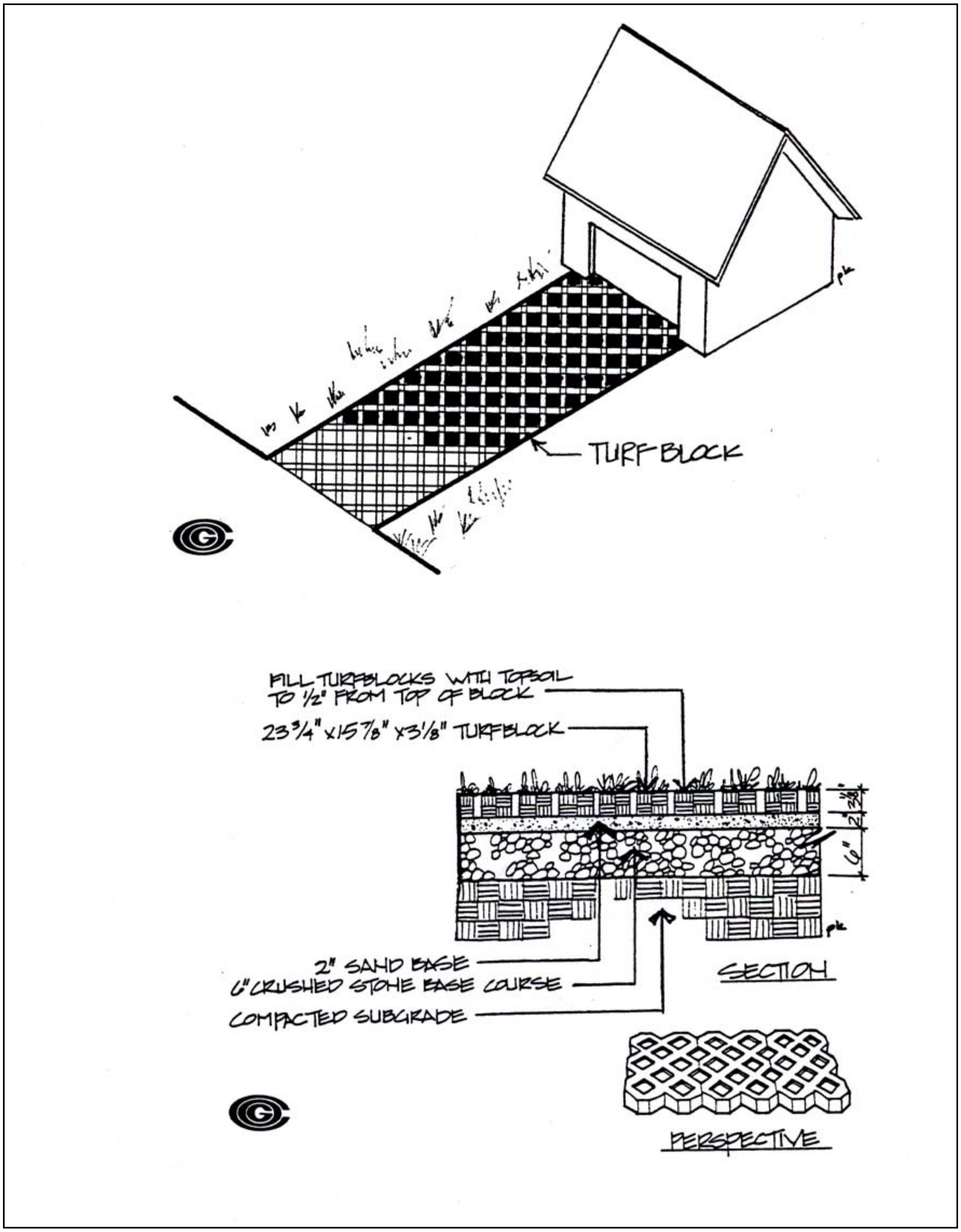

Figure E.3 Schematic of Permeable Pavers
(Source: Metropolitan Washington Council of Governments, 1993)

Grass Channels

Grass channels are typically designed to meet runoff velocity targets for the water quality design storm (Figure E.4). Runoff velocity should not exceed 1.0 foot per second during the peak discharge associated with the water quality design rainfall event, and the total length of the channel should provide at least five minutes of residence time. In some regions of the country, grass channels are termed “biofilters.” To meet the water quality criteria, grass channels must have broader bottoms, lower slopes and denser vegetation than most drainage channels. Nominal pretreatment is created by placing checkdams across the channel below pipe inflows, and at various other points along the channel. The filter bed area in a grass channel is usually confined to the top inch of soil and thatch, since most runoff events will traverse the length of channel in ten minutes or less. Grass channels must be designed per the Stormwater Design Manual’s Grass Channel Credit specifications (http://www.mde.state.md.us/assets/document/chapter5.pdf).

Advantages

- Generally result in reduced impervious cover compared with curb and gutter designs
- Can act to partially infiltrate runoff from small storm events if underlying soils are adequate
- Can be used as part of the runoff conveyance system to provide pretreatment
- If designed well, can provide moderate pollutant removal of particulate pollutants
- Can be an easy retrofit on traditional drainage channels

Limitations

- Possible impact on local groundwater quality
- Standing water in residential channels will not be popular with adjacent residents for aesthetic reasons and because of potential safety, odor, and mosquito problems
- Potential for bottom erosion and resuspension
- Lower pollutant removal rates (may actually be a source for some pollutants like bacteria associated with pet wastes)
- Ineffective unless carefully designed to achieve slow flow rates in the channel
- Ineffective if a dense vegetative cover cannot be established

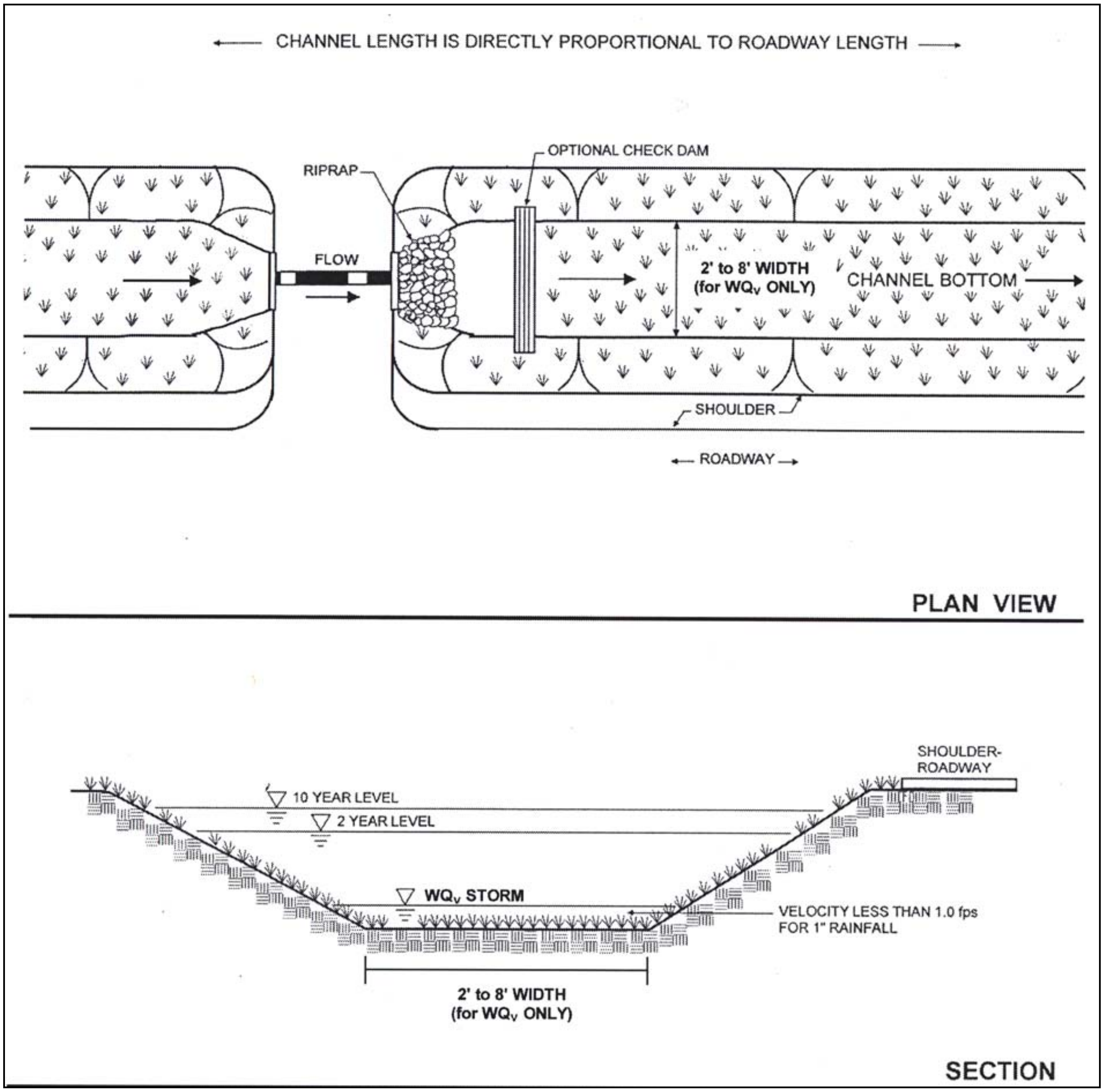

Figure E.4 Schematic of Grass Channels
(Source: Maryland Stormwater Design Manual, 2000)

Approved on a Case-by-Case Basis

Porous Pavement

These systems are designed to infiltrate water through the porous upper layer into a storage reservoir of stone aggregate below (Figure E.5). The runoff eventually either percolates into the ground or runs out of the stone reservoir through an underdrain collection system. Use of porous pavement is typically limited to light traffic roads, parking lot overflow areas, and driveways.

Advantages

- Diverts surface runoff to groundwater recharge and, in some cases, provides even greater recharge than pre-development conditions
- Can provide stormwater quantity and quality treatment on-site
- Reduces pavement ponding
- Fair to good removal rates for sediment nutrients, organic matter, and trace metals

Limitations

- Slight to moderate risk of groundwater contamination depending on soil conditions and aquifer susceptibility
- Possible transport of hydrocarbons from vehicles and leaching of toxic chemicals from asphalt surface
- High failure rate potential
- Extended rain can reduce the pavement’s load bearing capacity
- Requires sophisticated level of construction and regular maintenance
- No sanding for de-icing permitted
- Possible cracking in freezing weather conditions
- Only feasible where soil is permeable, there is sufficient depth to bedrock and water table, and there are gentle slopes
- Not suitable for areas with high traffic volume
- More expensive than traditional paving surfaces

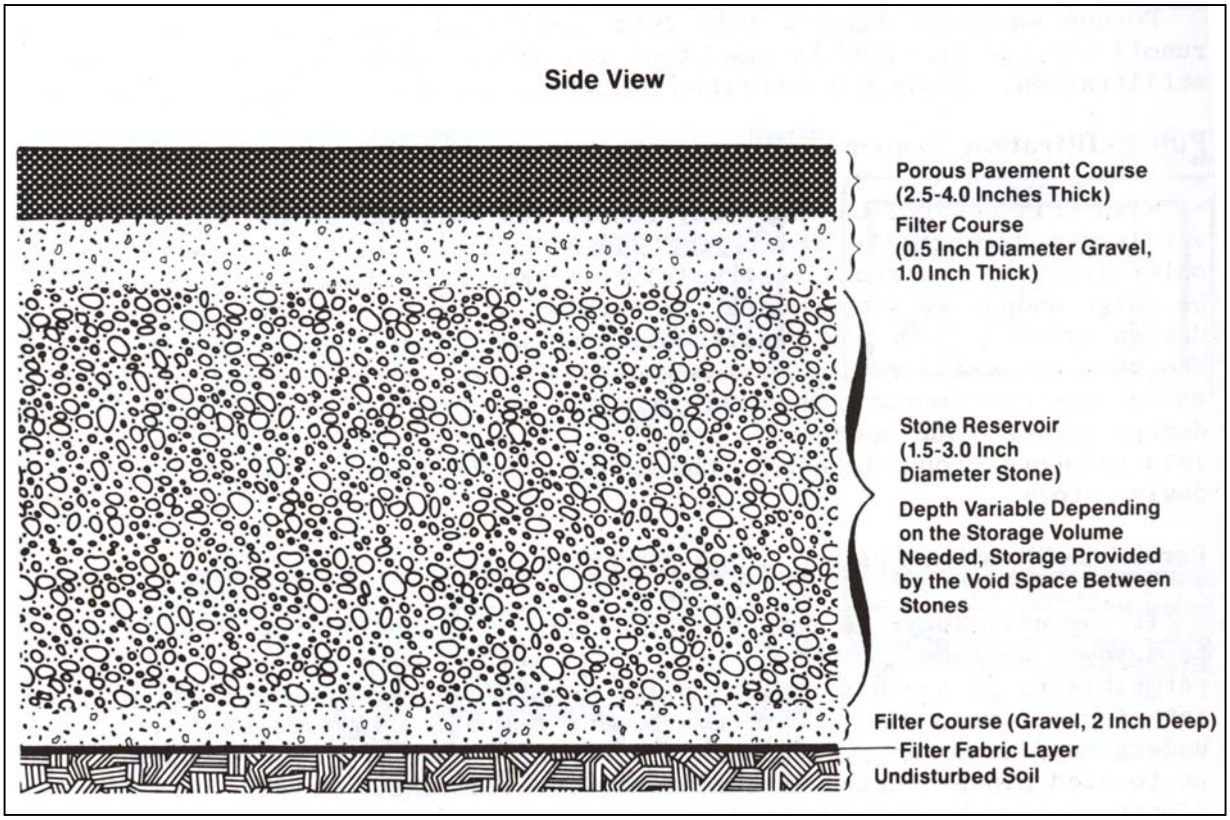

Figure E.5 Schematic of Porous Pavement
(Source: City of Rockville, MD, 1984)

<u>Cisterns</u>
Cisterns are roof water collection devices that provide retention storage volume in above-ground or underground storage tanks (Figure E.6). The water collected can be used for lawn and garden watering, household graywater needs or drinking water supply. Cisterns are generally larger than rain barrels, with some underground cisterns having capacities of 10,000 gallons. Storing rainwater on-site for later re-use also provides an opportunity for water conservation and the possibility of reducing water utility costs (LID Center, 2003).

Advantages
- Cisterns can reduce the volume of water entering public systems through rooftop storage of large amounts of rainfall
- Promotes water conservation and increased public awareness and
- Reduces water utility bills
- Can be retrofit into existing communities
- Requires little space

Disadvantages
- Requires strong landowner buy-in
- Can be relatively expensive compared to rain barrels
- If collected water is used for drinking, expensive filtration and treatment systems may be required

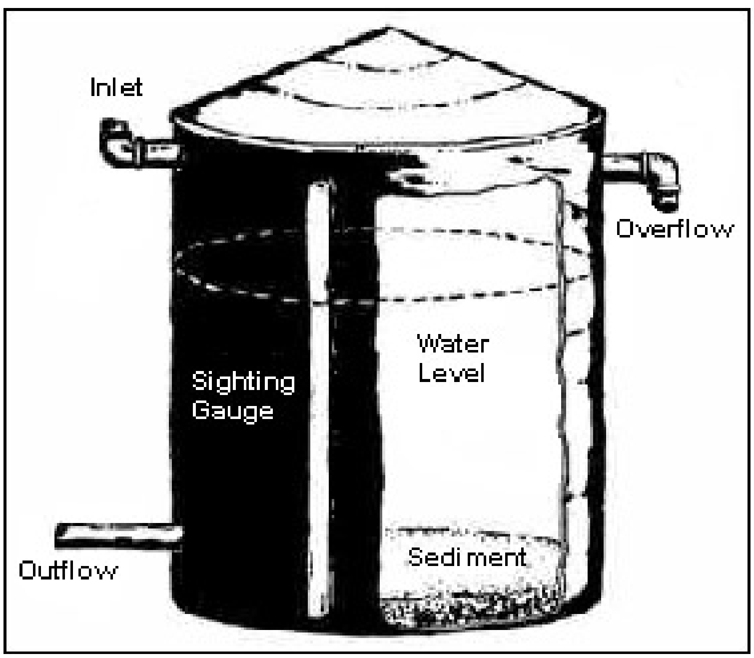

Figure E.6 Cistern
(Source: Texas Guide to Rainwater Harvesting, 2003)

STRUCTURAL BMPS

Structural BMPs are grouped into six general categories:

- Stormwater Ponds
- Stormwater Wetlands
- Infiltration Practices
- Filtering Practices
- Grass Channel Practices

Much of the information and schematics presented in this section were directly taken from the Maryland Stormwater Design Manual. Additional information regarding the design and sizing of structural BMPs can be found in the Maryland Stormwater Design Manual at: http://www.mde.state.md.us/assets/document/chapter3.pdf

Stormwater Ponds

Micropool Extended Detention (ED) Pond

Micropool extended detention ponds are variations of wet ED ponds where a small "micropool" is maintained at the outlet to the pond that prevents resuspension of previously settled sediments and also prevents clogging of the low flow orifice (Figure E.7). The rest of the facility's remaining storage above the permanent pool drains down.

Advantages

- Less expensive pond option
- High pollutant removal efficiency and downstream channel protection when properly designed and maintained
- Can be designed for combined flood control and stormwater quality control

Limitations

- Inability to vegetate banks and bottom above permanent pool may result in erosion and resuspension of sediments
- Limitation of the water quality orifice diameter may preclude use in small watersheds
- May create mosquito breeding conditions and other nuisances

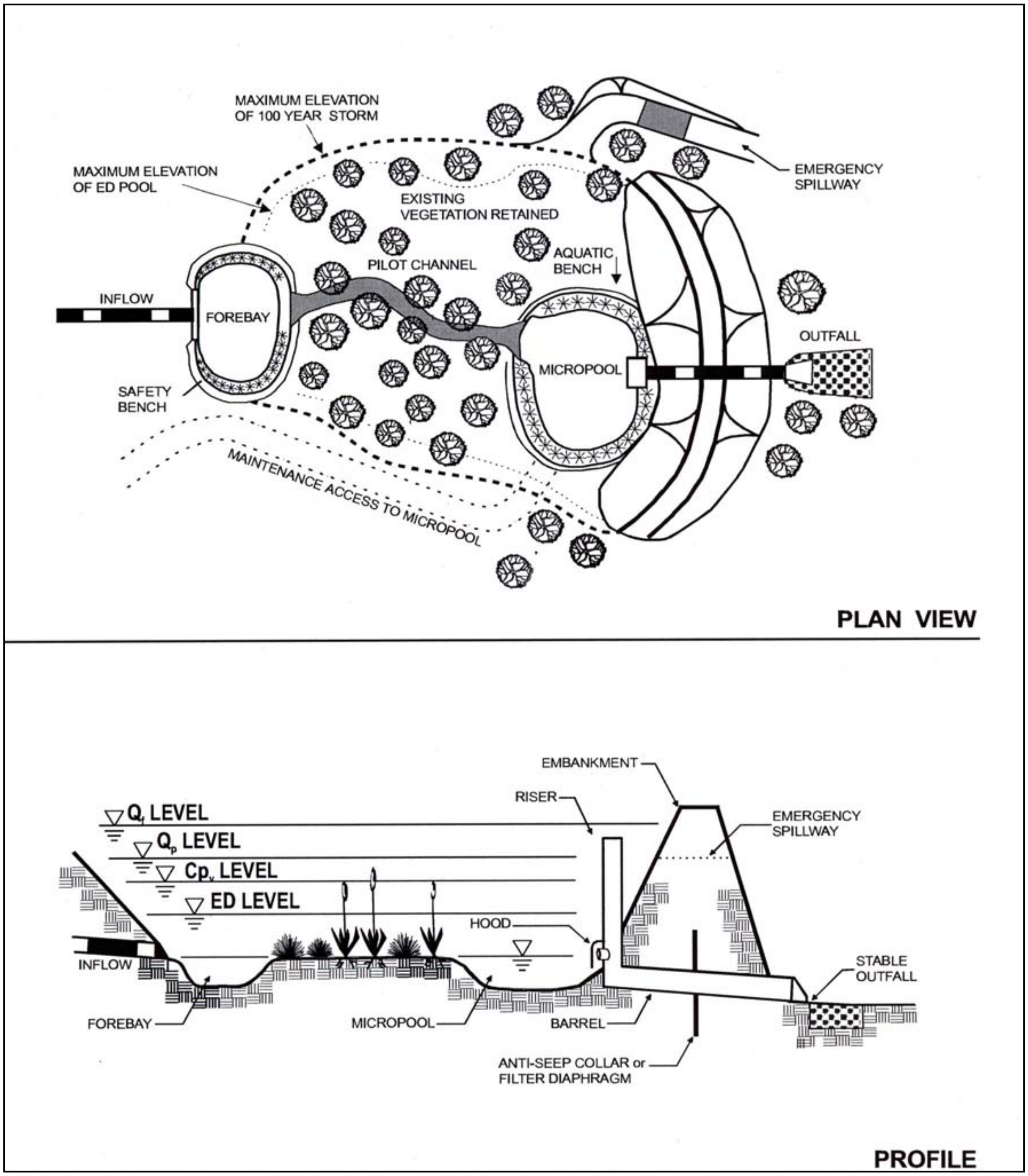

Figure E.7 Schematic of Micropool Extended Detention Pond
(Source: Maryland Stormwater Design Manual, 2000)

Wet Pond

Wet ponds are constructed facilities with a permanent pool of water (dead storage) throughout most of the year that treats incoming stormwater runoff through gravitational settling and other means. Wet ponds typically provide additional temporary storage (live storage) for runoff control of the water quantity design storms. Water levels and stormwater controls are managed by the use of risers, orifices, and/or other outlet control structures (Figure E.8).

Advantages

- Creation of aquatic and terrestrial habitat (particularly for waterfowl)
- High community acceptance, landscaping, and amenity potential
- High pollutant removal efficiency and downstream channel protection when properly designed and maintained
- Permanent pool helps to prevent scour and resuspension of sediments
- Can be designed for combined flood control and stormwater quality control
- Limited risk of groundwater quality impacts over the long term
- Can provide uptake of soluble pollutants such as phosphorus, through biological activity
- Can be used as a regional facility

Limitations

- Cannot be placed on steep unstable slopes
- Need base flow or supplemental water if water level is to be maintained
- Often infeasible in very dense urban areas due to space requirements
- Downstream warming can shift trophic status
- Upstream channels can be heavily impacted when wet ponds are "on line" and serve large drainage areas (> 250 acres)
- Potential loss of wetlands, forest and floodplain habitat associated with poor site selection for the pool
- Potential safety hazard for public
- May need liner in highly permeable soils
- Require a large drainage area (> 10 acres) to retain the permanent pool
- Depth limitations will apply in coastal areas (low relief usually requires facilities to be fully excavated) and karst regions (head build-up can cause piping)

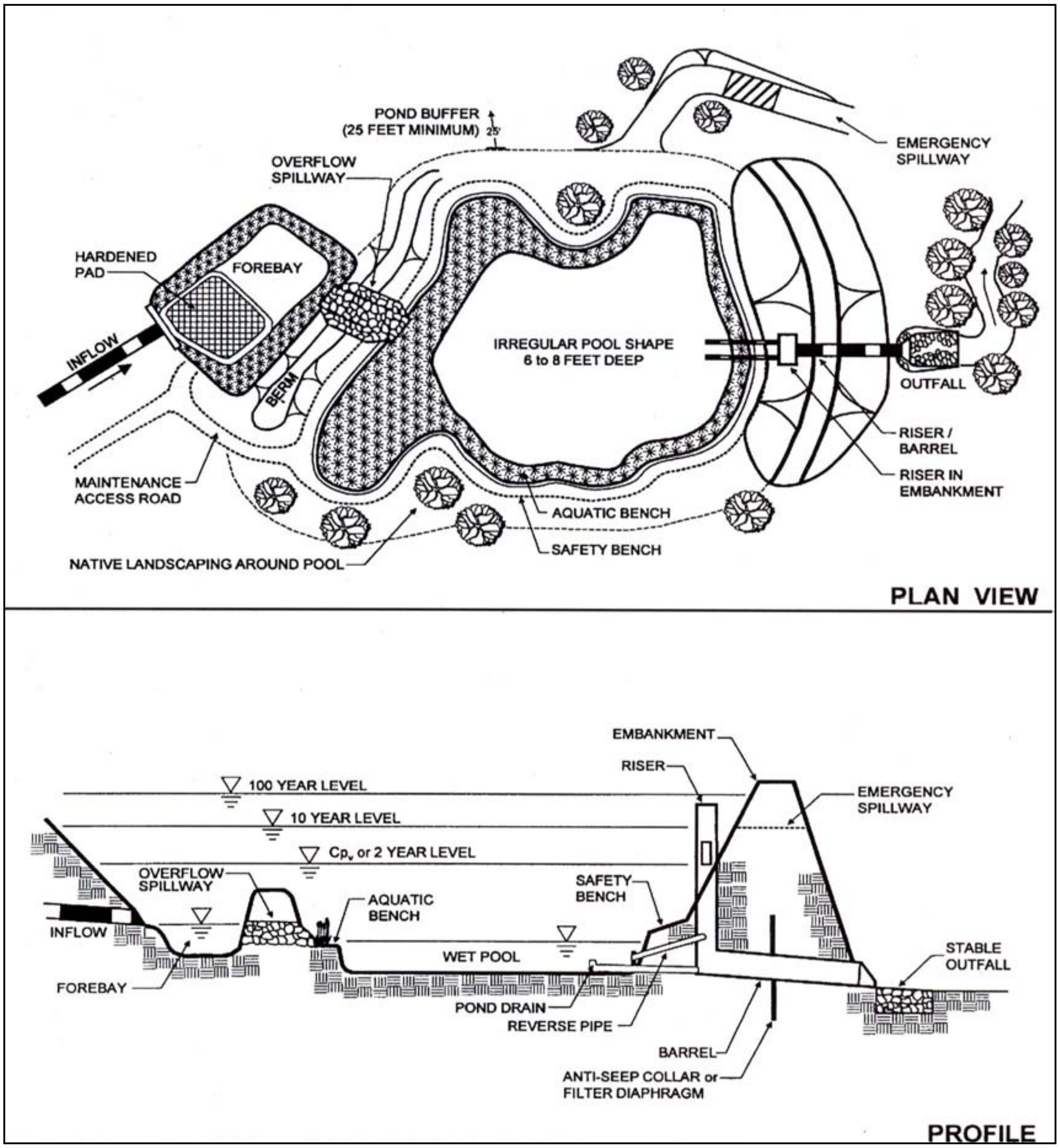

Figure E.8 Schematic of Wet Pond
(Source: Maryland Stormwater Design Manual, 2000)

Wet Extended Detention (ED) Pond

Wet ED ponds are constructed facilities that incorporate both a permanent pool and extended detention storage above the permanent pool of a water quality design storm for some minimum time (e.g., 24 hours) to allow for settling of particles and associated pollutants (Figure E.9). These ponds can also be utilized for flood control by including additional temporary storage for larger storm peak flows (e.g., 10-year return frequency).

Advantages

- Can create both terrestrial and aquatic wildlife habitat with appropriate pondscaping and vegetation management
- Small permanent pool allows sedimentation to occur in confined location; maintenance is relatively easier
- Can be designed for combined flood control and stormwater quality control
- High pollutant removal efficiency and downstream channel protection when properly designed and maintained
- Can provide uptake of soluble pollutants such as phosphorus, through plant uptake and other biological processes
- Less hazardous than other stormwater ponds with deeper permanent pools

Limitations

- Improper site selection can create wetland, forest and habitat conflicts
- May need liner in highly permeable soils
- Possible thermal and oxygen depleted discharge can impact downstream aquatic life
- Need base flow or supplemental water if water level is to be maintained
- May be inappropriate in dense urban areas due to space concerns
- Requires a large drainage area (> 25 acres) to retain the permanent pool

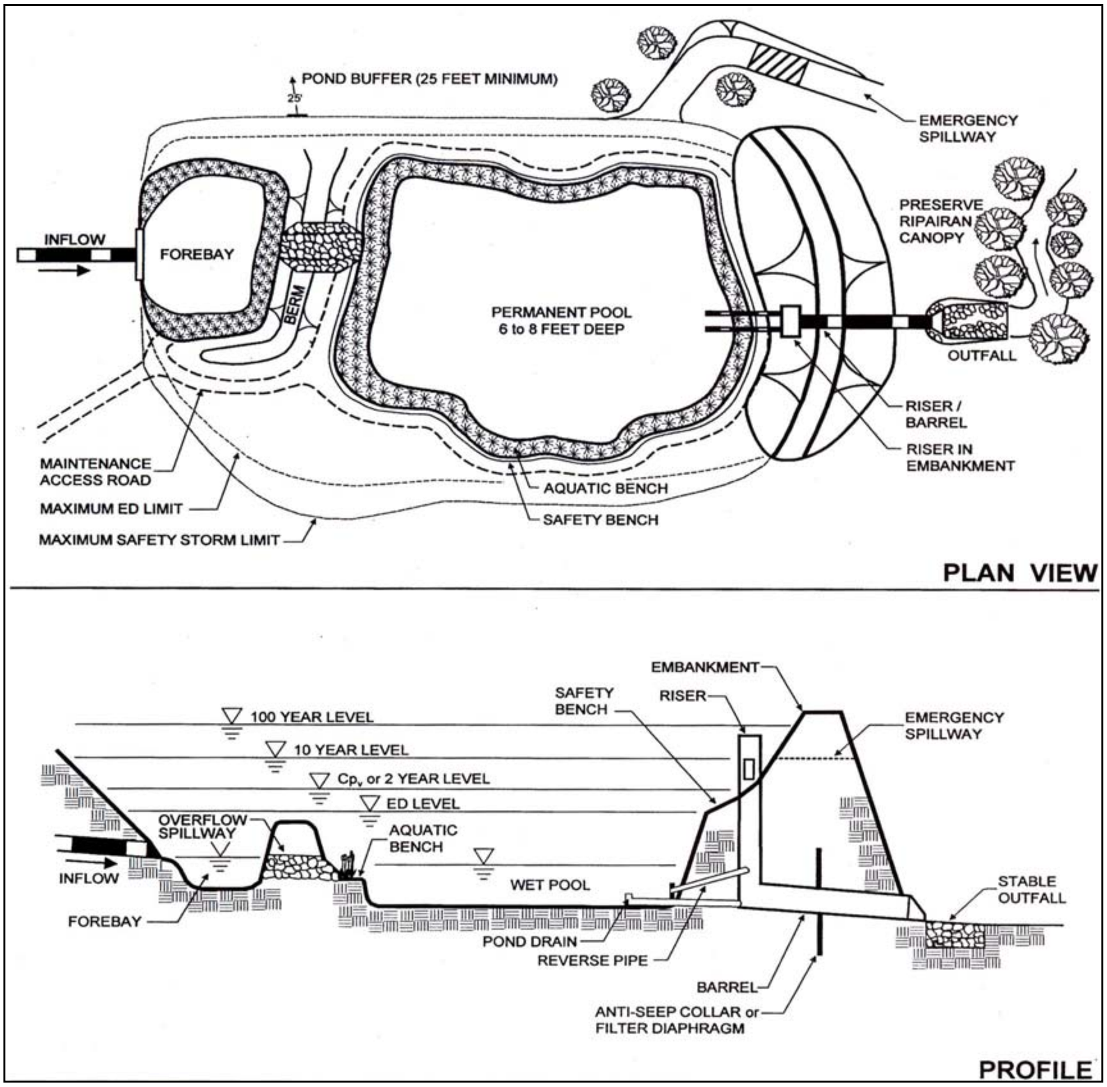

Figure E.9 Schematic of Wet Extended Detention Pond
(Source: Maryland Stormwater Design Manual, 2000)

Multiple Pond Systems

Multiple pond systems consist of constructed facilities that provide water quality and quantity volume storage in two or more cells. The additional cells create longer pollutant removal pathways in stormwater discharge (Figure E.10).

Advantages

- Provide higher and more consistent levels of urban pollutant removal than a single treatment system due to longer flow paths and increased retention time
- Enhance habitat value
- High pollutant removal efficiency and downstream channel protection when properly designed and maintained
- Can be designed for combined flood control and stormwater quality control

Limitations

- Most expensive pond option due to complex design
- Large land requirement
- May need liner in highly permeable soils

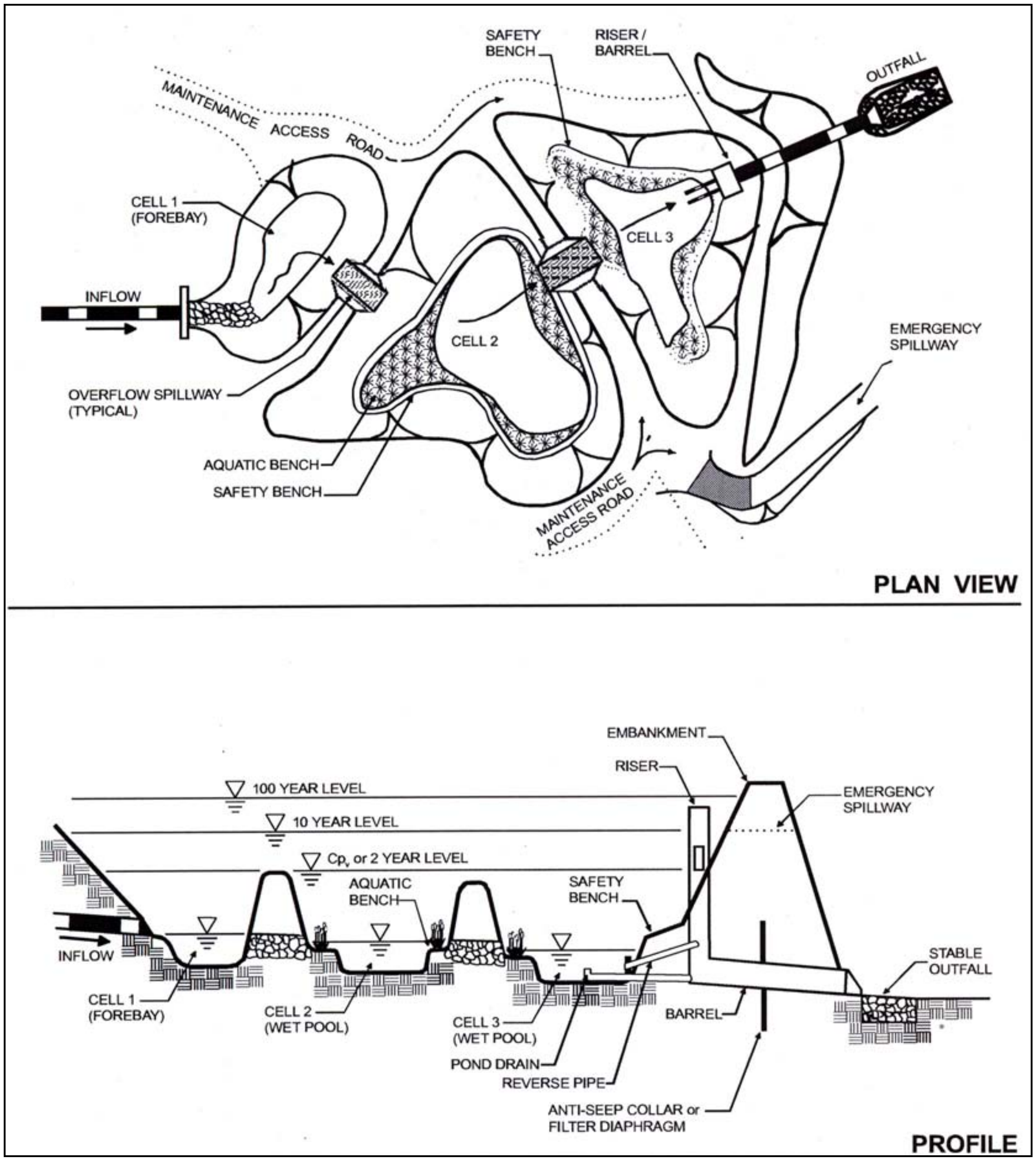

Figure E.10 Schematic of Multiple Pond System
(Source: Maryland Stormwater Design Manual, 2000)

<u>Pocket Pond</u>

The pocket pond is a stormwater pond design adapted for the treatment of runoff from small drainage areas that has little or no baseflow available to maintain water elevations (Figure E.11). While this design achieves less pollutant removal than a traditional wet pond, it may be an acceptable alternative on sites where space is at a premium, or in a retrofit situation. Excavation to groundwater interception should be avoided where the land uses draining to the pond may contaminate drinking water supplies.

Advantages

- Can be used on site where space is at a premium, or in a retrofit situation

Limitations

- Somewhat high maintenance requirements
- Wet ground adjacent to the pond may provide a breeding ground for mosquitoes
- Low habitat and amenity value

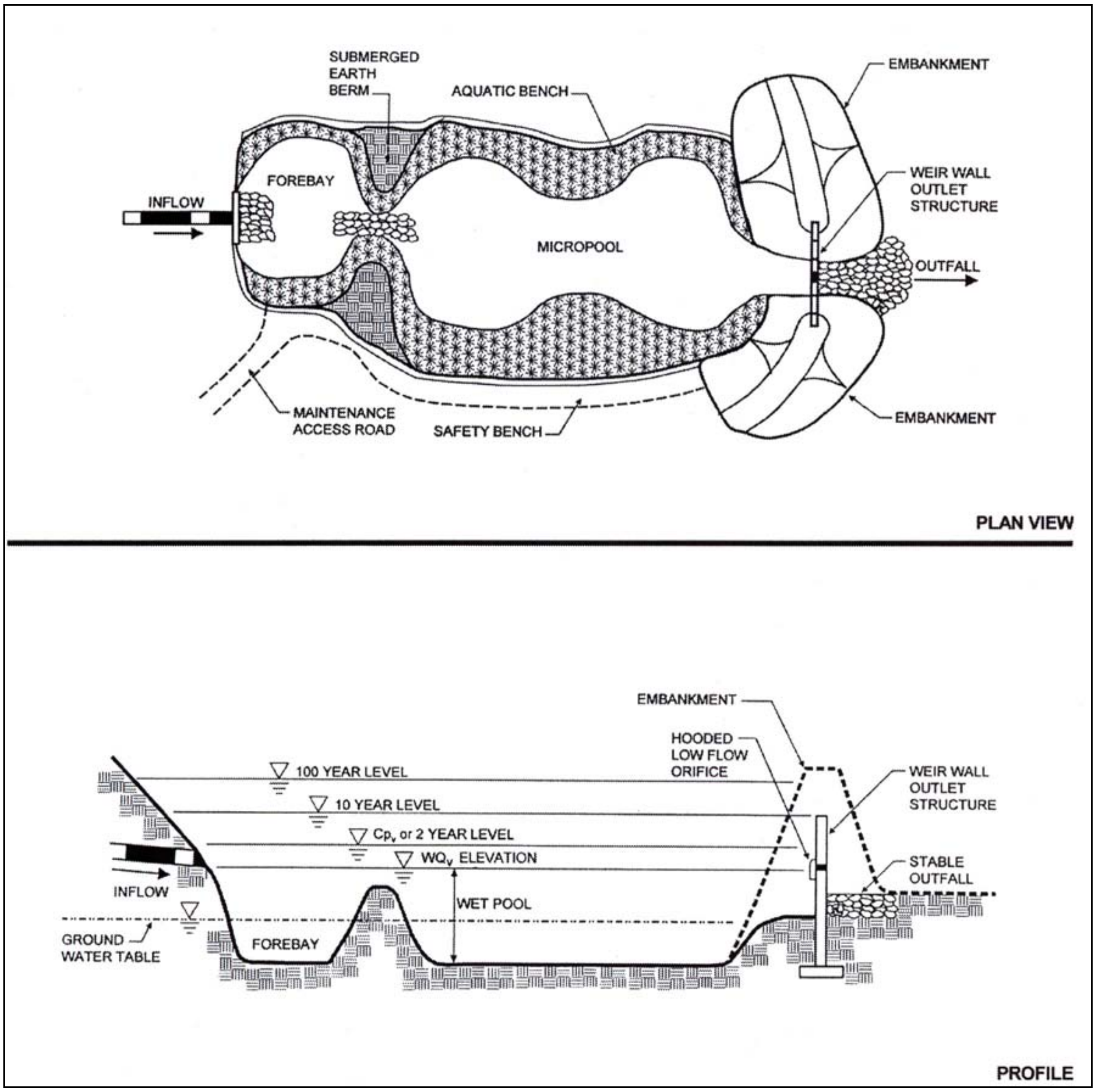

Figure E.11 Schematic of Pocket Pond
(Source: Maryland Stormwater Design Manual, 2000)

Stormwater Wetlands

Shallow Wetland

The shallow wetland is a constructed system that temporarily stores stormwater runoff in shallow pools, creating growing conditions suitable for emergent and riparian wetland plants (Figure E.12). The shallow wetland design has a large surface area, and requires a reliable source of baseflow or groundwater supply to maintain the desired water elevations to support emergent wetland plants. Typically, the shallow system requires a lot of space and a sizeable contributing watershed area (often in excess of 25 acres) to support the shallow permanent pool.

Advantages

- Can provide an excellent urban habitat for wildlife and waterfowl, particularly if they are surrounded by a buffer and have some deeper water areas
- Good removal of sediments and nutrients, and can provide uptake of soluble pollutants through plant uptake
- Can be designed for combined flood and stormwater quality control

Limitations

- Inappropriate in highly urban areas due to space concern
- Best used with large drainage areas (> 25 acres) to ensure a water balance
- Construction may adversely impact existing wetland or forest areas
- Possible takeover by invasive aquatic nuisance plants
- Possible bacteria contamination if waterfowl populations become very dense
- Cannot be placed on steep unstable slopes
- Need base flow to maintain water level
- Nutrient release may occur during dormant period

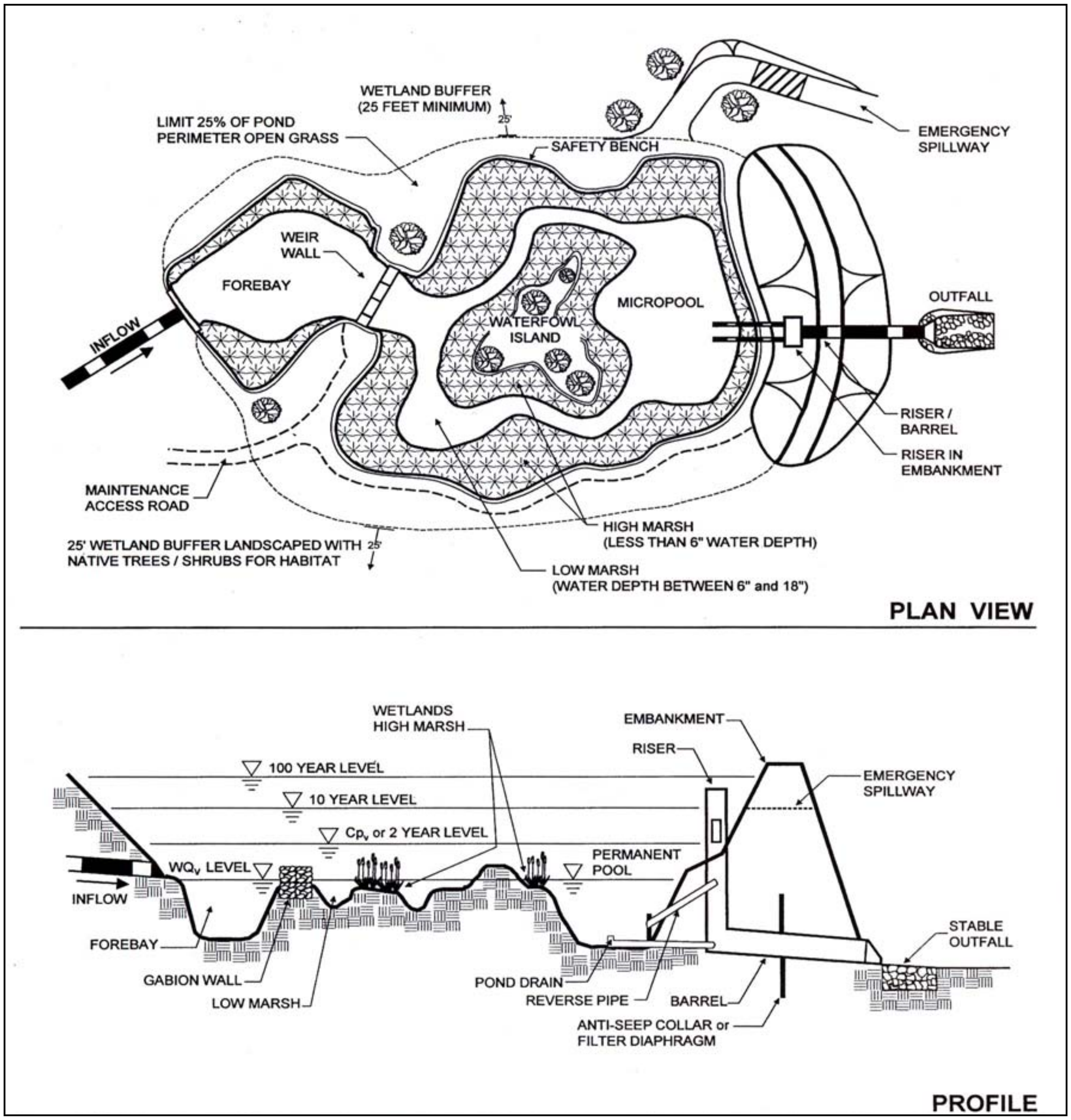

Figure E.12 Schematic of Shallow Wetland
(Source: Maryland Stormwater Design Manual, 2000)

Extended Detention (ED) Shallow Wetland

In ED shallow wetlands, extra storage is created above the shallow marsh by temporary detention of runoff (Figure E.13). The ED feature enables the wetland to consume less space, as temporary vertical storage is partially substituted for shallow wetland storage. Along the side-slopes of ED wetlands, a new growing zone is created that extends from the normal pool elevation to the maximum ED water surface elevation.

Advantages

- Can provide an excellent urban habitat for wildlife and waterfowl, particularly if they are surrounded by a buffer and have some deeper water area
- Good removal of sediments and nutrients, and can provide uptake of soluble pollutants through plant uptake and biological activity
- Can be designed for combined flood and stormwater quality control
- Can be used as a regional facility

Limitations

- Inappropriate in highly urban areas due to space concerns
- Best used with large drainage areas (> 25 acres) to ensure a water balance
- Construction may adversely impact existing wetland or forest areas
- Overgrowth can lead to reduced hydraulic capacity
- Possible takeover by invasive aquatic nuisance plants
- Possible bacteria contamination if waterfowl populations become very dense
- Cannot be placed on steep unstable slopes
- Need base flow to maintain water level
- Nutrient release may occur during dormant season

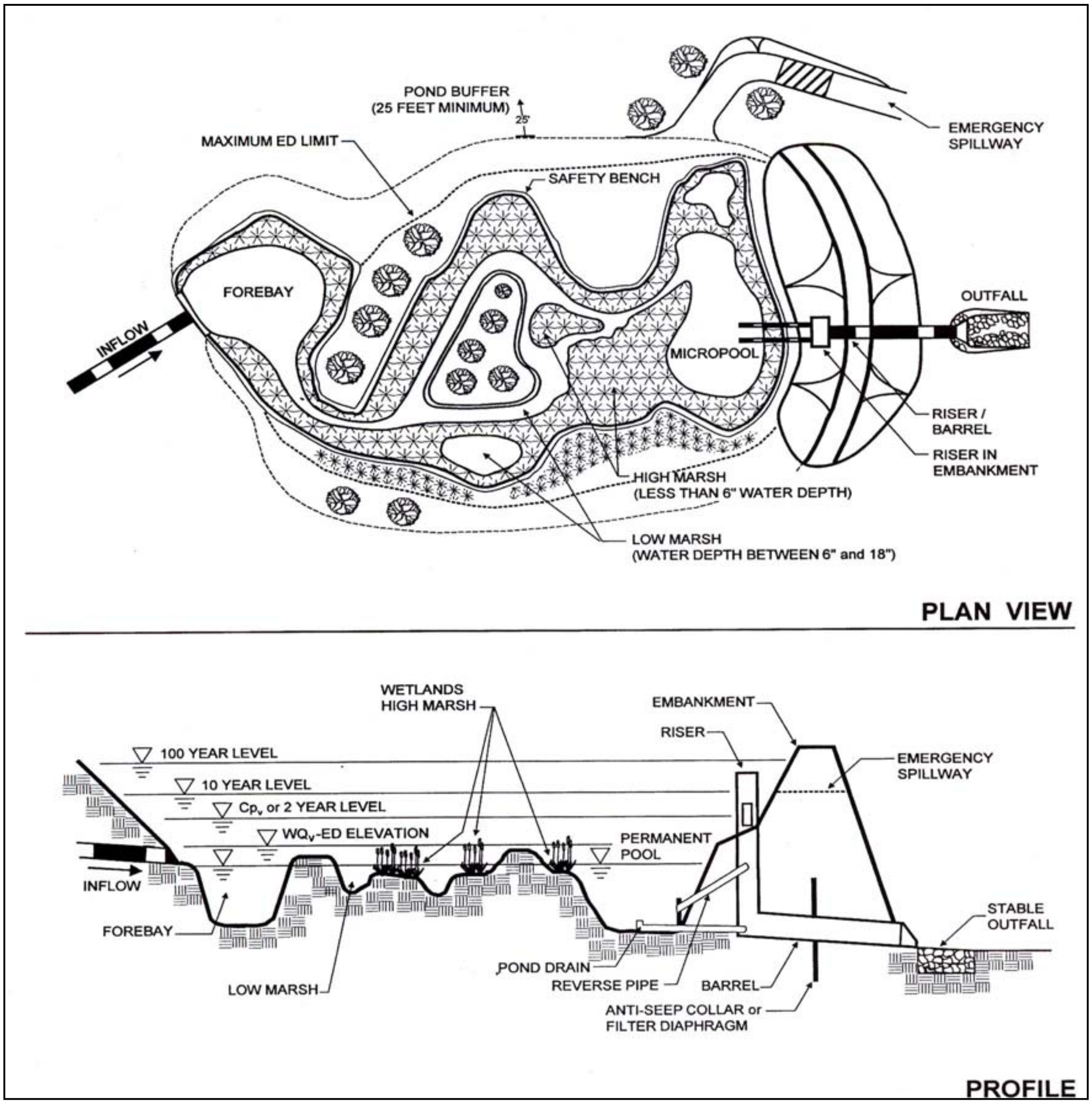

Figure E.13 Schematic of Shallow ED Wetland
(Source: Maryland Stormwater Design Manual, 2000)

<u>Pond/Wetland System</u>
The pond/wetland system combines the wet pond design with a shallow wetland (Figure E.14). Stormwater runoff flows through the wet pond and into the shallow marsh. Like the extended detention wetland, this design requires less surface area than the shallow marsh because some of the volume of the practice is in the relatively deep (i.e., six to eight feet) pond.

Advantages
- High community acceptance rate
- Requires little maintenance
- Can provide an excellent urban habitat for wildlife and waterfowl, particularly if they are surrounded by a buffer and have some deeper water area
- Good removal of sediments and nutrients, and can provide uptake of soluble pollutants through plant uptake and biological activity
- Can be designed for combined flood and stormwater quality control

Limitations
- Inappropriate in highly urban areas due to space concerns
- Best used with large drainage areas (> 25 acres) to ensure a water balance
- Construction may adversely impact existing wetland or forest areas
- Overgrowth can lead to reduced hydraulic capacity
- Possible takeover by invasive aquatic nuisance plants
- Possible bacteria contamination if waterfowl populations become very dense
- Concern for mosquitoes
- Cannot be placed on steep unstable slopes
- Need base flow to maintain water level
- Nutrient release may occur during dormant season

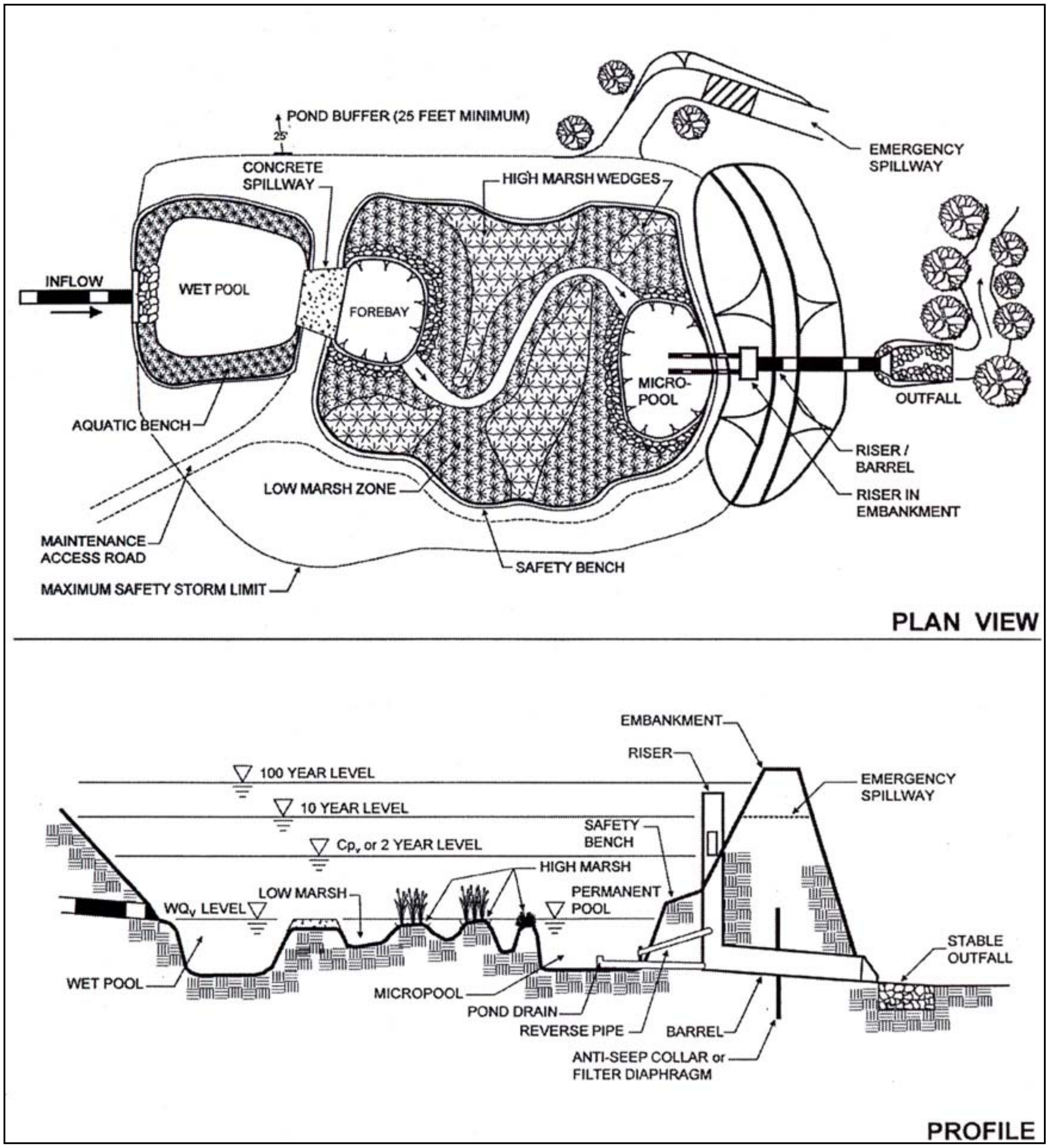

Figure E.14 Schematic of Pond/Wetland System
(Source: Maryland Stormwater Design Manual, 2000)

Pocket Wetland

Pocket wetlands (Figure E.15) are adapted to serve smaller sites from one to ten acres in size. Because of their small drainage areas, pocket wetlands usually do not have a reliable source of baseflow, and therefore exhibit widely fluctuating water levels. In most cases, water levels in the wetland are supported by excavating down to the water table. During extended periods of dry weather, the wetland may not have a shallow pool at all (only saturated soils). Due to their small size and fluctuating water levels, pocket wetlands often have low plant diversity and poor wildlife habitat value.

Advantages

- Can be located in space limited sites (i.e., ultra urban settings)
- Can be effective stormwater retrofit practice
- Good pollutant removal for both particulate and soluble pollutants
- Can provide quantity control as well

Limitations

- Cost relative to drainage area served is comparatively high
- Need base flow or high water table to maintain water level
- Possible takeover by invasive aquatic nuisance plants
- Overgrowth can lead to reduced hydraulic capacity

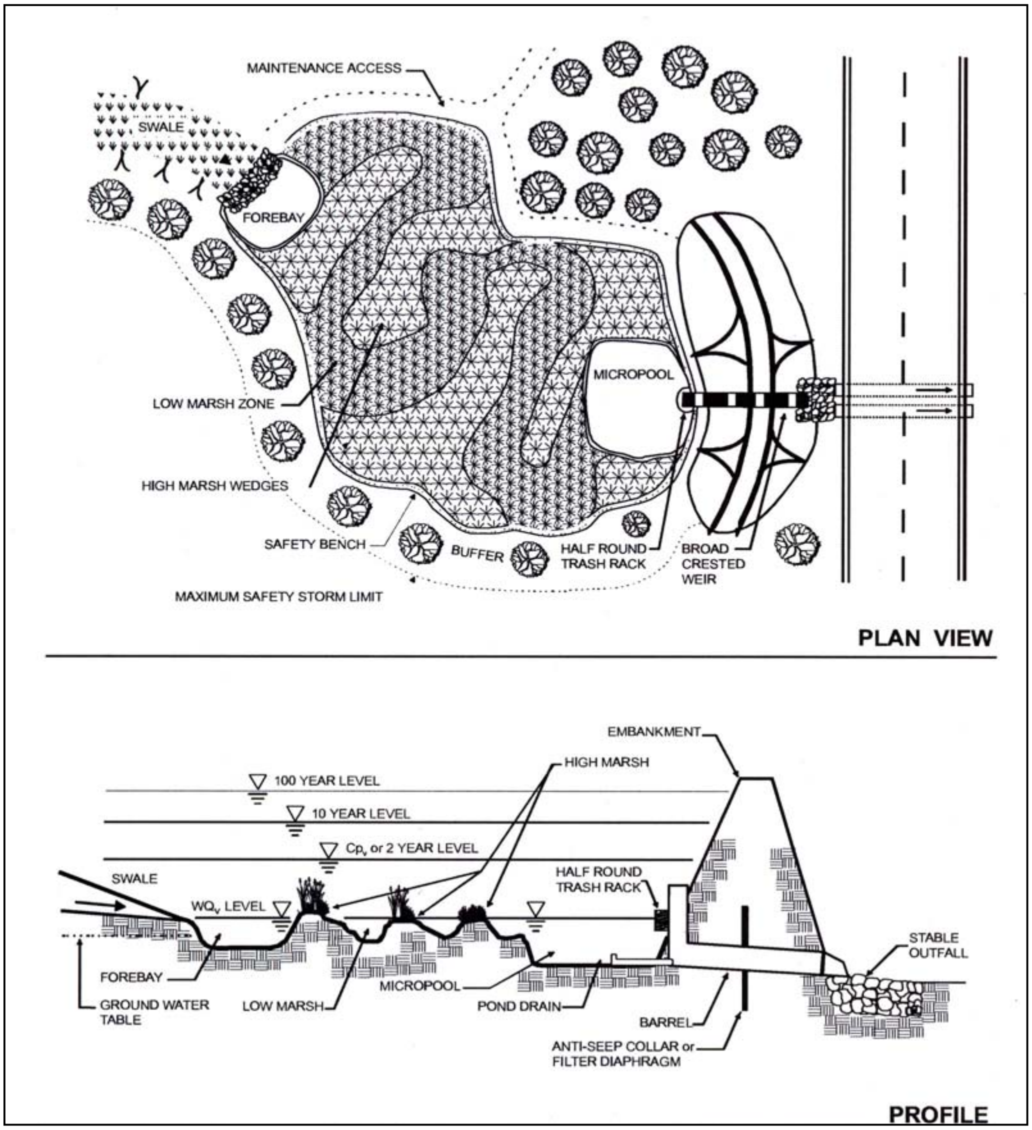

Figure E.15 Schematic of Pocket Wetland System
(Source: Maryland Stormwater Design Manual, 2000)

Stormwater Infiltration Practices

Infiltration Trench

Infiltration trenches are shallow (two to ten feet deep) trenches in relatively permeable soils that are lined with filter fabric and backfilled with a sand filter and coarse stone. The trench surface can be covered with grating and/or consist of stone, gabion, sand, or a grass covered area with a surface inlet. Depending on the design, trenches allow for the partial or total infiltration of stormwater runoff into the underlying soil (Figure E.16). Infiltration trenches can be quality and quantity facilities.

Advantages

- Provides groundwater recharge
- Can minimize increases in runoff volume
- Can serve small drainage areas
- Can fit into medians, perimeters, and other unused areas of a development site
- Helps replicate predevelopment hydrology and increases dry weather baseflow
- Good pollutant removal capabilities

Limitations

- Slight to moderate risk of groundwater contamination depending on soil conditions
- Metals and petroleum hydrocarbons could accumulate in soils to potentially toxic levels
- No habitat is created
- High failure rates of conventional trenches and high maintenance burden
- Only feasible where soil is permeable and there is sufficient depth to bedrock and water table
- Since not as visible as other BMPs, less likely to be maintained
- Not recommended for discharge to a sole source aquifer
- Should not be used if upstream sediment load cannot be controlled prior to entry into the trench
- Should only be applied on small (< 5 acre) sites

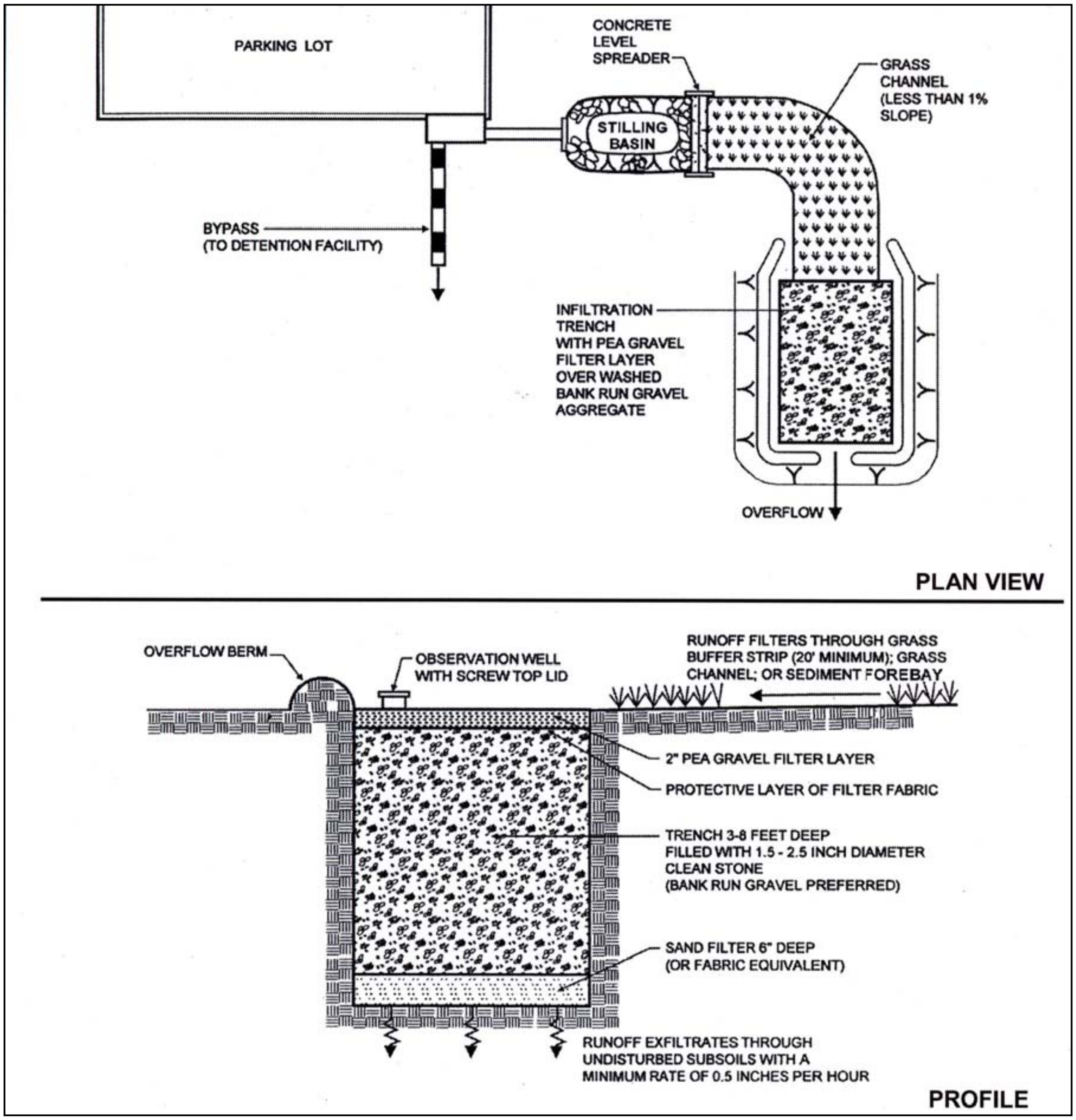

Figure E.16 Schematic of Infiltration Trench
(Source: Maryland Stormwater Design Manual, 2000)

Infiltration Basin

Infiltration basins are depressions created by excavation, berms, or small dams to provide short-term ponding of surface runoff until it percolates into the soil (Figure E.17). Infiltration basins can be sized for both water quality and water quantity design storms; however, use of this practice should be restricted to areas with permeable soils (i.e., Hydrologic Soil Groups A and B).

Advantages

- Groundwater recharge helps to maintain dry-weather flows in streams
- Can minimize increases in runoff volume
- High removal capability for particulate pollutants and moderate removal for soluble pollutants
- When properly designed and maintained, it can replicate predevelopment hydrology more closely than other BMP options
- Basins provide more habitat value than other infiltration systems

Limitations

- Slight to moderate risk of local groundwater contamination (particularly if contributing watershed is industrial or has heavy vehicular petroleum washoff).
- Metal and petroleum hydrocarbons could accumulate in soils to potentially toxic levels
- Relatively large land requirement
- High failure rate due to clogging and high maintenance burden
- Only feasible where soil is permeable and there is sufficient depth to bedrock and water table
- Not recommended for discharge to a sole source aquifer
- Should not be used if significant upstream sediment load exists

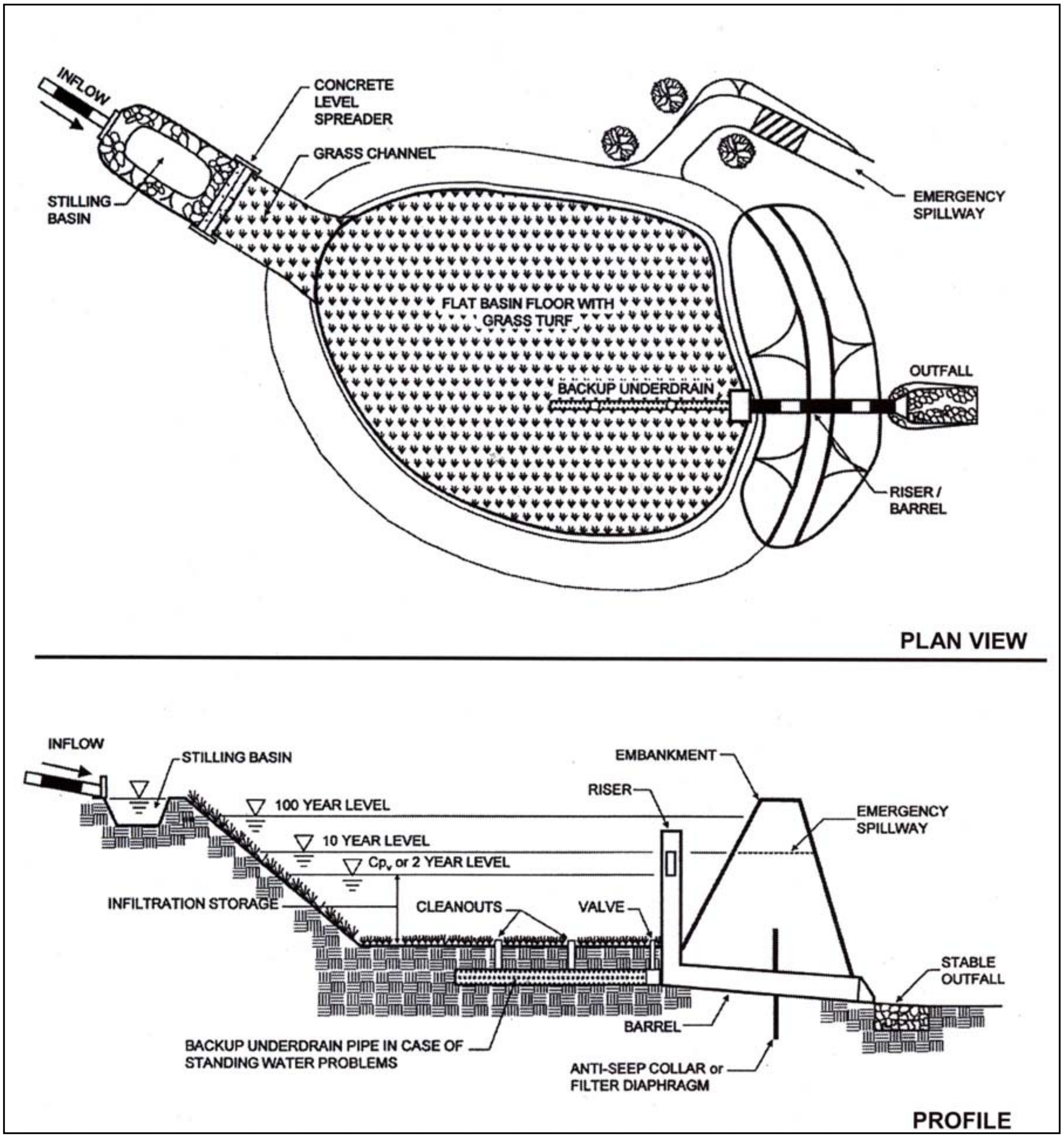

Figure E.17 Schematic of Infiltration Basin
(Source: Maryland Stormwater Design Manual, 2000)

Stormwater Filtering Practices

Surface Sand Filter

In the surface sand filter, a flow splitter is used to divert the first flush of runoff into an off-line sedimentation chamber. The chamber may be either wet or dry, and is used for pretreatment. Runoff is then distributed into the second chamber, which consists of a sand filter bed (±18”) and temporary runoff storage above the bed (Figure E.18). Pollutants are trapped or strained out at the surface of the filter bed. The filter bed surface may have a sand or grass cover. A series of perforated pipes located in a gravel bed collect the runoff passing through the filter bed, and return it to the stream or channel at a downstream point. If underlying soils are permeable, and groundwater contamination unlikely, the bottom of the filter bed may have no lining, and the filtered runoff may be allowed to exfiltrate.

Advantages

- Useful in watersheds where concerns over groundwater quality or site conditions prevent use of infiltration
- High pollutant removal capability
- Can be used in highly urbanized settings
- Can be designed for a variety of soils
- Ideal for aquifer regions

Limitations

- Requires frequent maintenance to prevent clogging
- Available head to meet design criteria
- Dissolved pollutants are not captured by sand
- Larger sand filter designs, without grass cover, may be unattractive and generate odors
- Concrete walls that surround the sand filter can represent a safety hazard
- If the filter drains pervious surfaces, or large drainage areas, potential clogging by sediment is increased
- Generally best if limited to relatively small drainage areas (< 10 acres)

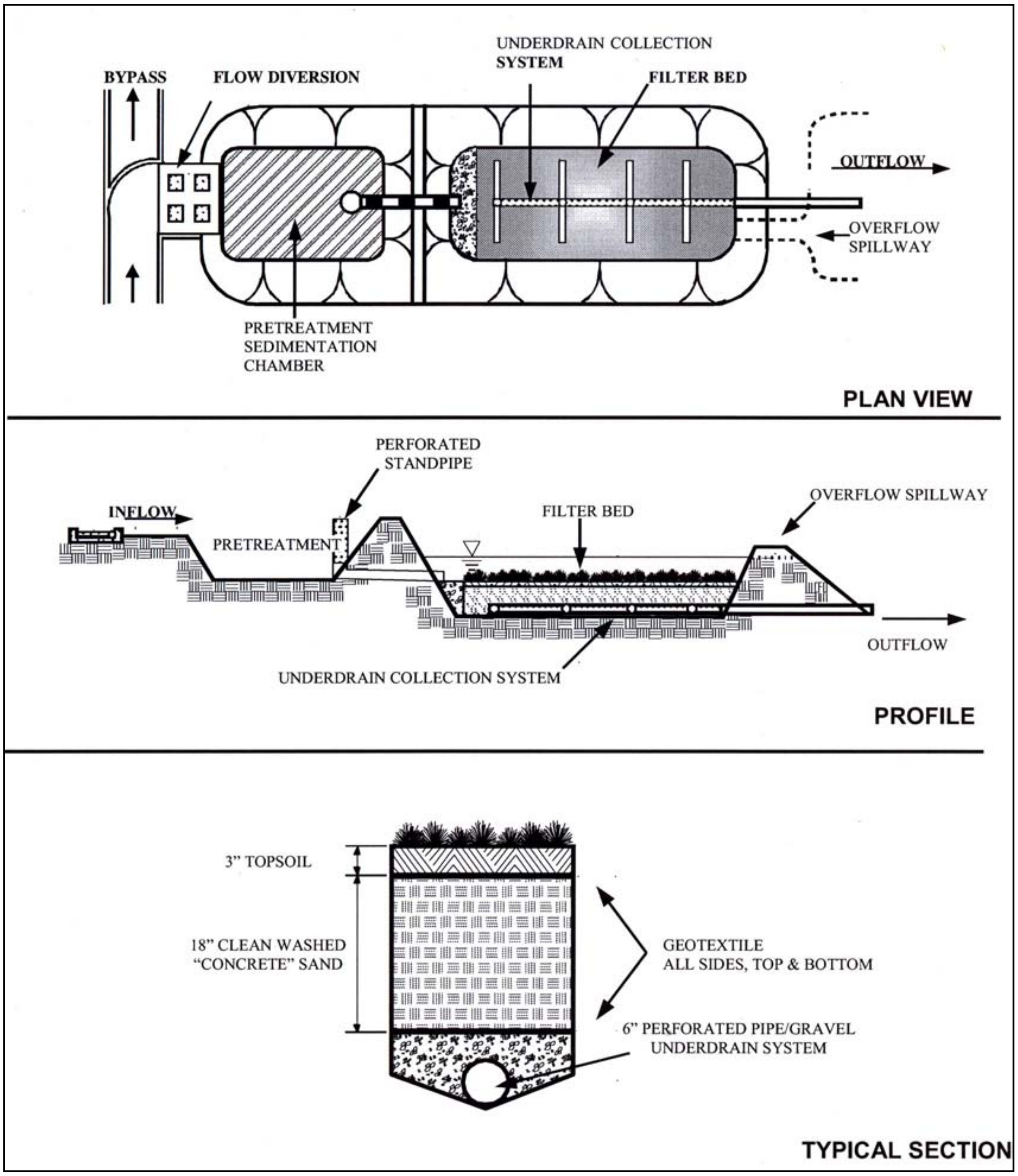

Figure E.18 Schematic of Surface Sand Filter
(Source: Maryland Stormwater Design Manual, 2000)

Underground Sand Filter

The underground sand filter was adapted for sites where space is at a premium. In this design, the sand filter is placed in a three chamber underground vault accessible by manholes or grate openings. The vault can be either on-line or off-line in the storm drain system. The first chamber is used for pretreatment and relies on a wet pool, as well as temporary runoff storage. It is connected to the second sand filter chamber by an inverted elbow, which keeps the filter surface free from trash and oil. The filter bed is 18 inches deep and may have a protective screen of gravel or permeable geotextile to limit clogging (Figure E.19). During a storm, the water quality volume is temporarily stored in both the first and second chambers. Flows in excess of the filter's capacity are diverted through an overflow weir. Filtered runoff is collected, using perforated underdrains that extend into the third “overflow” chamber.

Advantages
- Useful in watersheds where concerns over groundwater quality prevent use of infiltration
- High pollutant removal capability
- Do not take up surface area
- Can be used in highly urbanized settings
- Can be designed for a variety of soils
- Ideal for aquifer regions

Limitations
- Requires frequent maintenance to prevent clogging
- Available head to meet design criteria
- Dissolved pollutants are not captured by sand
- Generally function only as a stormwater quality practice and do not provide detention for downstream areas
- If the filter drains pervious surfaces, or large drainage areas, potential clogging by sediment is increased
- Inspection needs to be vigilant because this BMP is “out of sight”
- Generally best if limited to small drainage areas (< 2 acres)

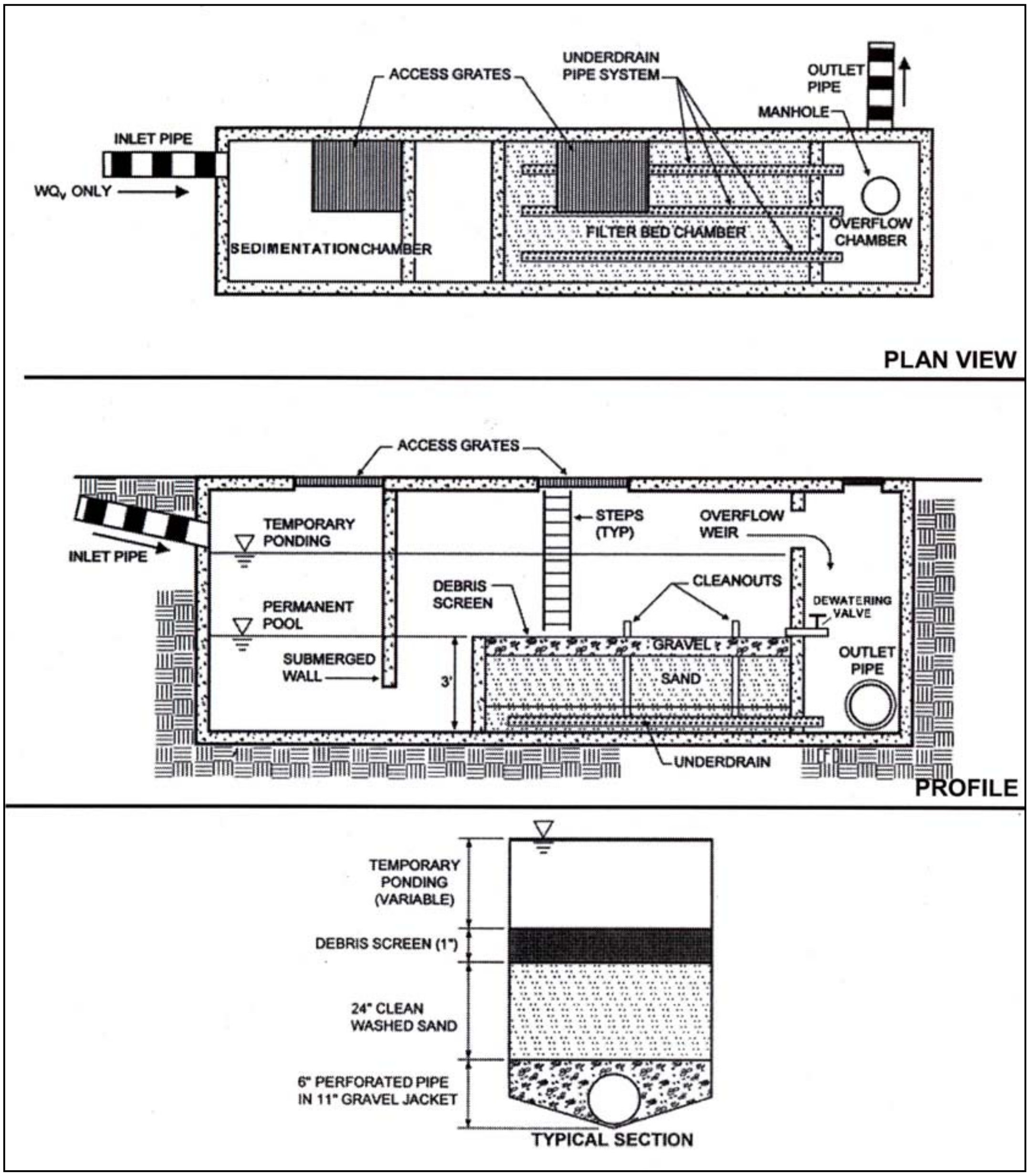

Figure E.19 Schematic of Underground Sand Filter
(Source: Maryland Stormwater Design Manual, 2000)

Perimeter Sand Filter

The perimeter sand filter consists of two parallel trench-like chambers that are typically installed along the perimeter of a parking lot. Parking lot runoff enters the first chamber, which has a shallow permanent pool of water (Figure E.20). The first trench provides pretreatment before the runoff spills into the second trench, which consists of a sand layer (±18”). During a storm event, runoff is temporarily ponded above the normal pool and sand layer, respectively. When both chambers fill up to capacity, excess parking lot runoff is routed to a bypass drop inlet. The remaining runoff is filtered through the sand, and collected by underdrains and delivered to a protected outflow point.

Advantages

- Sand filters are useful in watersheds where concerns over groundwater quality prevent use of infiltration
- High pollutant removal capability
- Do not take up surface area
- Can be used in highly urbanized settings
- Can be designed for a variety of soils
- Can be used in relatively flat terrain

Limitations

- Requires frequent maintenance to prevent clogging
- Available head to meet design criteria
- Dissolved pollutants are not captured by sand
- Generally function only as a stormwater quality practice and do not provide detention for downstream areas
- If the filter drains pervious surfaces, or large drainage areas, potential clogging by sediment is increased
- Inspection/maintenance needs to be vigilant because this BMP is “out of sight”
- Generally best if limited to small drainage areas (< 2 acres)

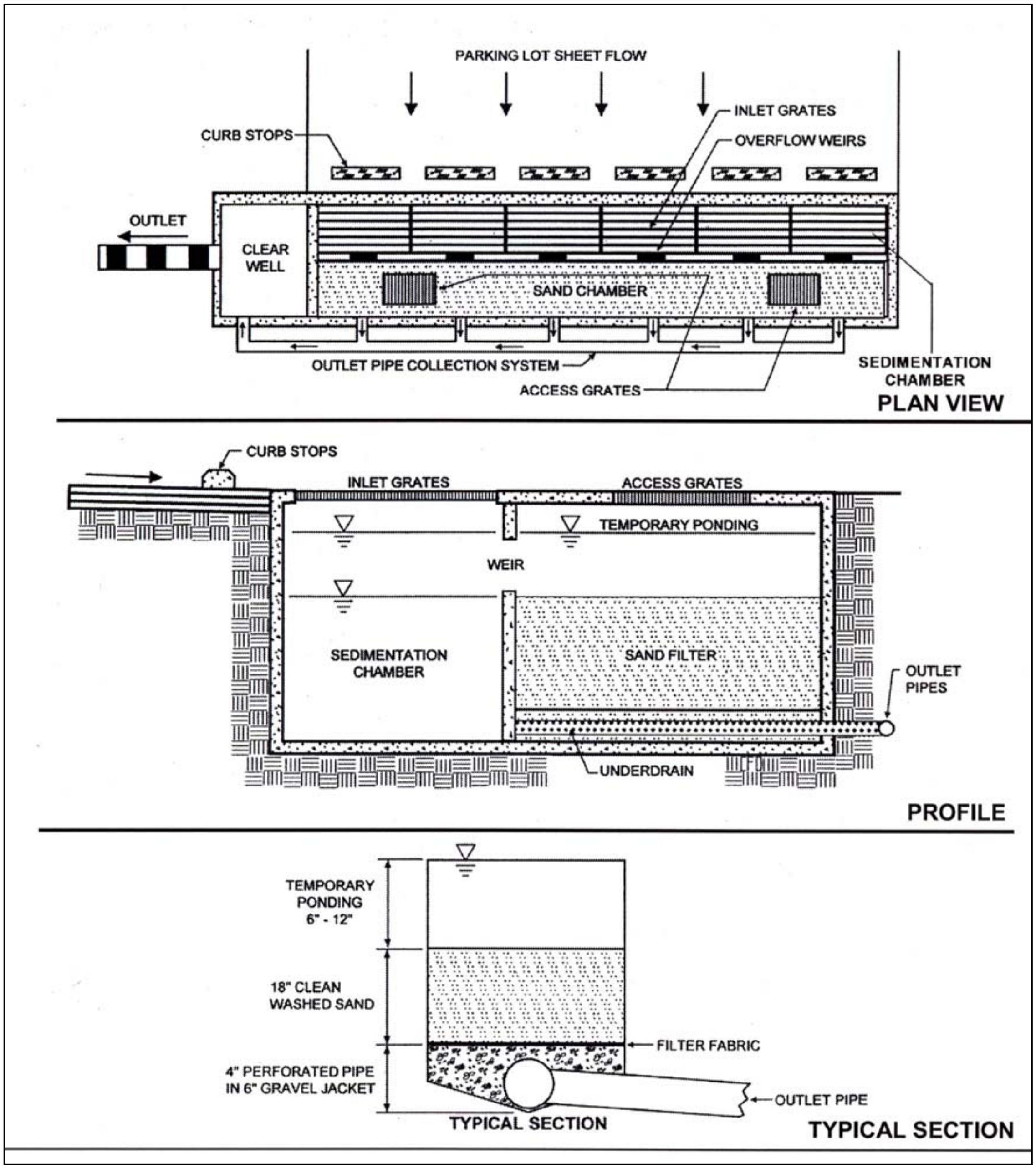

Figure E.20 Schematic of Perimeter Sand Filter
(Source: Maryland Stormwater Design Manual, 2000)

Organic Filter

The organic filter functions the same as a surface sand filter design, with the exception that it uses leaf compost or a peat/sand mixture as the filter media. The organic material enhances pollutant removal by providing adsorption of contaminants such as heavy metals. The organic filter consists of a flow splitter, which diverts runoff into a pretreatment chamber, and then passes into one or more filter cells (Figure E.21). Each filter bed contains a layer of leaf compost or the peat/sand mixture, followed by a filter fabric, and perforated pipe and gravel. Runoff filters through the organic media to the perforated pipe and ultimately to the outlet. The filter bed and subsoils can be separated by an impermeable polyliner to prevent movement into groundwater.

Advantages

- Organic filters are useful in watersheds where concerns over groundwater quality prevent use of infiltration
- High pollutant removal capability
- Removal of dissolved pollutants is greater than sand filters due to cation exchange capacity

Limitations

- Filter may require more frequent maintenance than most of the other BMPs
- Available head to meet design criteria
- Severe clogging potential if exposed soil surfaces exist upstream
- Larger organic filter designs, without grass cover, may not be attractive in residential areas and may cause odors
- Organic material for filter media may be difficult to obtain (especially for peat varieties)

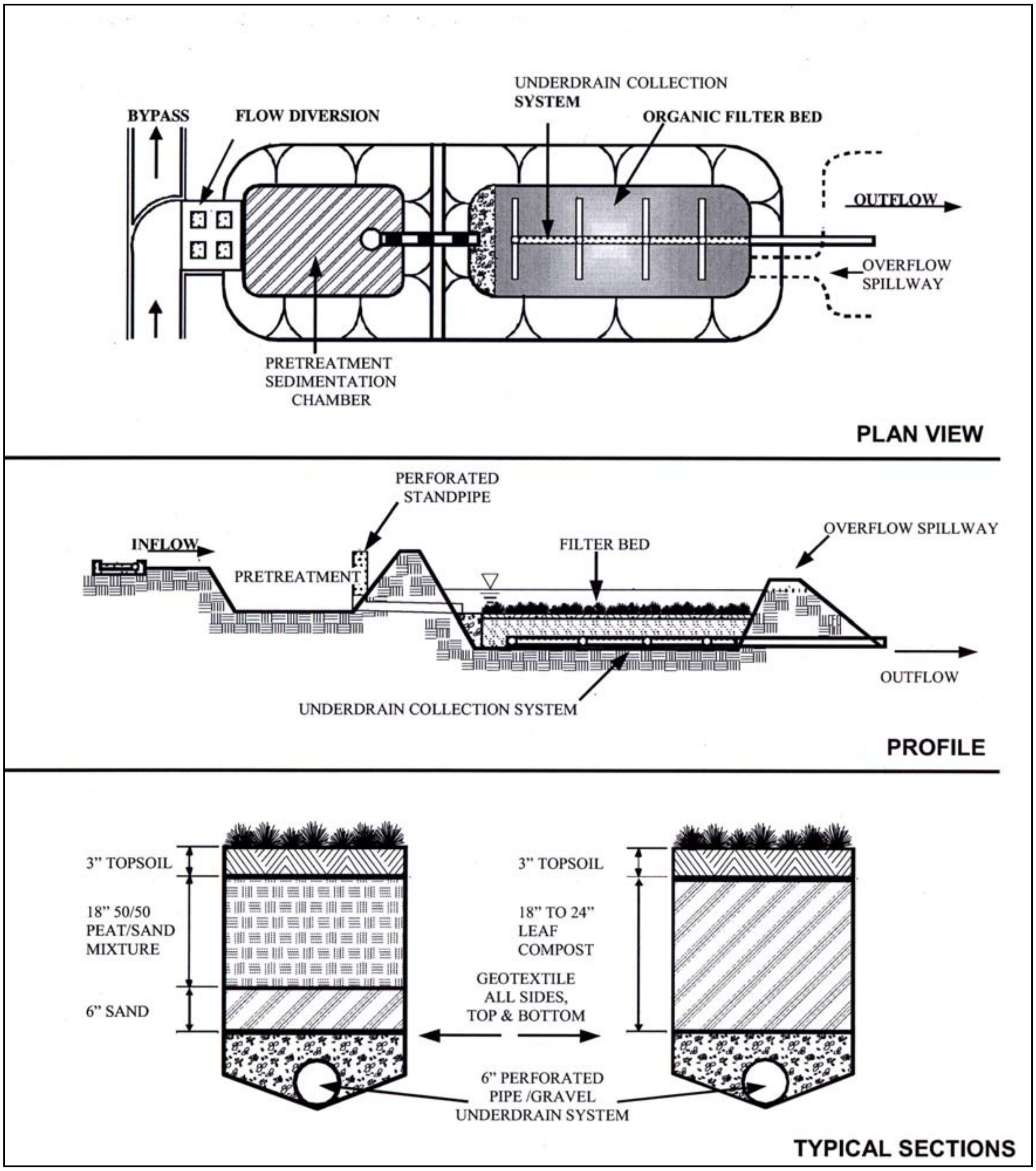

Figure E.21 Schematic of Organic Filter
(Source: Maryland Stormwater Design Manual, 2000)

Pocket Sand Filter

The pocket sand filter is a simplified and low cost design that may be used on smaller sites. Runoff is usually diverted within a manhole. A bypass pipe sends excess runoff along the storm drain system, and a flow diversion pipe routes the water quality volume into the system. Pretreatment is provided by a concrete flow spreader, a grass filter strip and a plunge pool (Figure E.22). For the filter bed, a shallow basin is excavated, and contains the sand filter layer. Most of the water quality volume is temporarily stored above the filter bed. The surface of the filter bed contains a soil layer and grass cover crop. In the event of clogging, the pocket sand filter has a pea gravel "window" to direct runoff into the sand, as well as a cleanout and observation well. In most cases, the filtered runoff is allowed to exfiltrate into the underlying soils, although underdrains may be needed if the soils are not suitably permeable.

Advantages

- Useful in watersheds where concerns over groundwater quality or site conditions prevent use of infiltration
- High pollutant removal capability
- Can be used in highly urbanized settings
- Can be designed for a variety of soils
- Ideal for aquifer regions

Limitations

- Requires frequent maintenance to prevent clogging
- Available head to meet design criteria
- Dissolved pollutants are not captured by sand
- Larger sand filter designs, without grass cover, may be unattractive and generate odors
- Concrete walls that surround the sand filter can represent a safety hazard
- If the filter drains pervious surfaces, or large drainage areas, potential clogging by sediment is increased
- Generally best if limited to a drainage area less than 2 acres

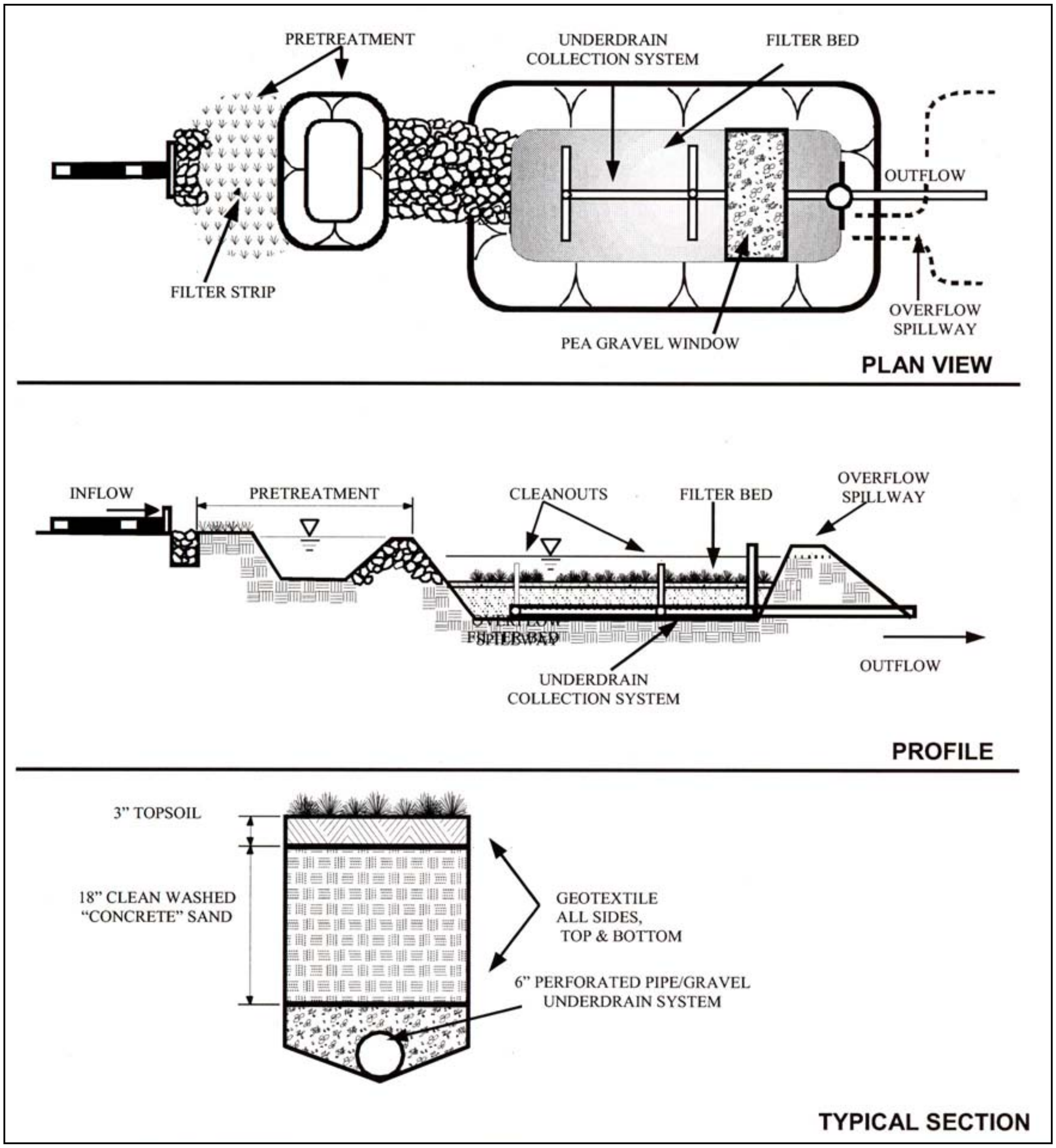

Figure E.22 Schematic of Pocket Sand Filter
(Maryland Stormwater Design Manual, 2000)

Bioretention

Bioretention filtering systems are adapted landscaping features used for on-site treatment of the water quality volume. They are commonly located in parking lot islands or within small pockets in residential land uses. Surface runoff is directed into shallow, landscaped depressions. These depressions are designed to incorporate many of the pollutant removal mechanisms that operate in forested ecosystems. During storms, the water quality volume is ponded up to nine inches above the mulch. Runoff in excess of the water quality volume rises to a higher elevation, but is then diverted into a standard drop inlet connected to the storm drain system. The remaining runoff filters through the mulch and prepared soil mix, which is about four feet deep (Figure E.23). Typically, the filtered runoff is collected in a perforated underdrain and returned to the storm drain system. If underlying soils are permeable, and groundwater contamination unlikely, the bottom of the filter bed may have no lining, and the filtered runoff may be allowed to exfiltrate.

Advantages

- Generally requires low land consumption, and can fit within the area that is typically devoted to landscaping
- Regular maintenance can be provided by commercial landscaping companies
- Removal of dissolved pollutants is more likely due to cation exchange capacity
- Can be used in highly urbanized settings
- Aesthetically pleasing

Limitations

- Available head to meet design criteria
- Requires frequent maintenance to prevent clogging, maintain landscaping, and remove litter
- Generally best if limited to small drainage areas (< 5 acres)

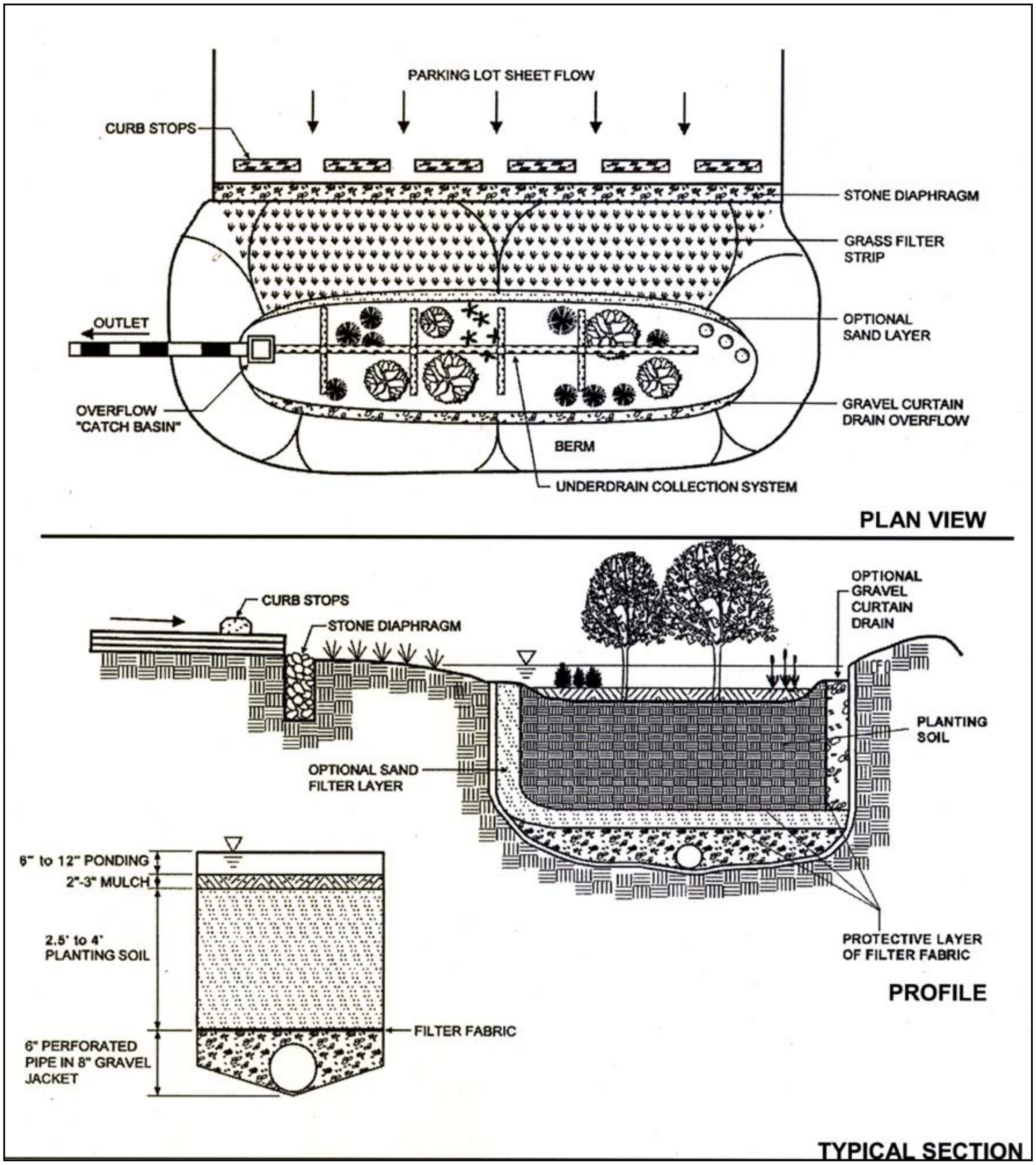

Figure E.23 Schematic of Bioretention
(Source: Maryland Stormwater Design Manual, 2000)

Open Channel Practices

Dry Swale

In a dry swale, the entire water quality volume is temporarily retained by checkdams during each storm. A dry swale also has a filter bed consisting of about 30 inches of prepared soil (sandy loam) that is then collected by an underdrain pipe. The swale is designed to rapidly dewater, thereby allowing swale to be more easily mowed. Pretreatment is provided through check dams and by keeping side slopes gentle if they are adjacent to impervious areas (Figure E.24). A dry swale is often the preferred grass channel option in residential settings since it is designed to prevent standing water that makes mowing difficult and generates complaints.

Advantages

- Generally results in reduced impervious cover compared with curb and gutter designs
- Good pollutant removal capabilities
- Can be used as conveyance system to provide pretreatment
- Ideal for low density residential and highway land uses
- Lower construction costs than curb and gutter

Limitations

- Can be difficult to avoid channelization in swales
- Cannot be placed on steep slopes
- Proper maintenance required to maintain health and density of vegetation
- Inappropriate in highly urbanized setting, due to space consumption

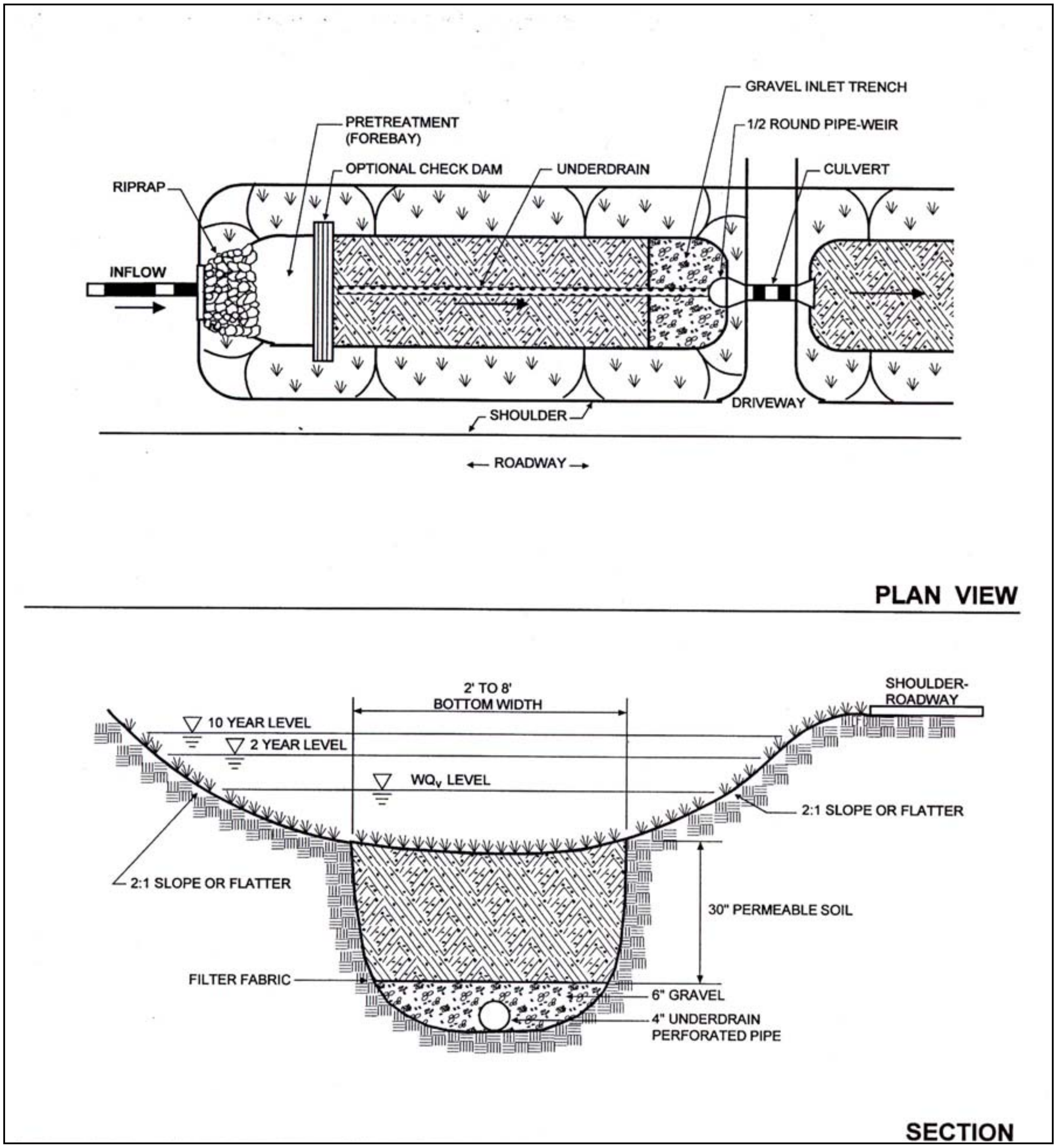

Figure E.24 Schematic of Dry Swale
(Source: Maryland Stormwater Design Manual, 2000)

Wet Swale

A wet swale is an grass channel design that occurs when the water table is located very close to the surface. As a result, swale soils often become fully saturated, or have standing water all or part of the year. The wet swale essentially acts as a linear shallow wetland treatment system. Like the dry swale, the entire water quality treatment volume is stored and retained within a series of cells in the channel, formed by berms or checkdams (Figure E.25). The notched checkdams are set so that the invert creates the pool level when the water table is high. In some cases, the cells may be planted with emergent wetland plant species to improve removal rates. If land is available, some wetland cells can be placed off-line.

Advantages

- Generally results in reduced impervious cover compared with curb and gutter designs
- Good pollutant removal capabilities
- Can be used as part of the runoff conveyance system to provide pretreatment
- Lower construction costs than curb and gutter

Limitations

- Requires high water table
- Can be difficult to avoid channelization
- Cannot be placed on steep slopes
- Not recommended for residential or more urban land uses

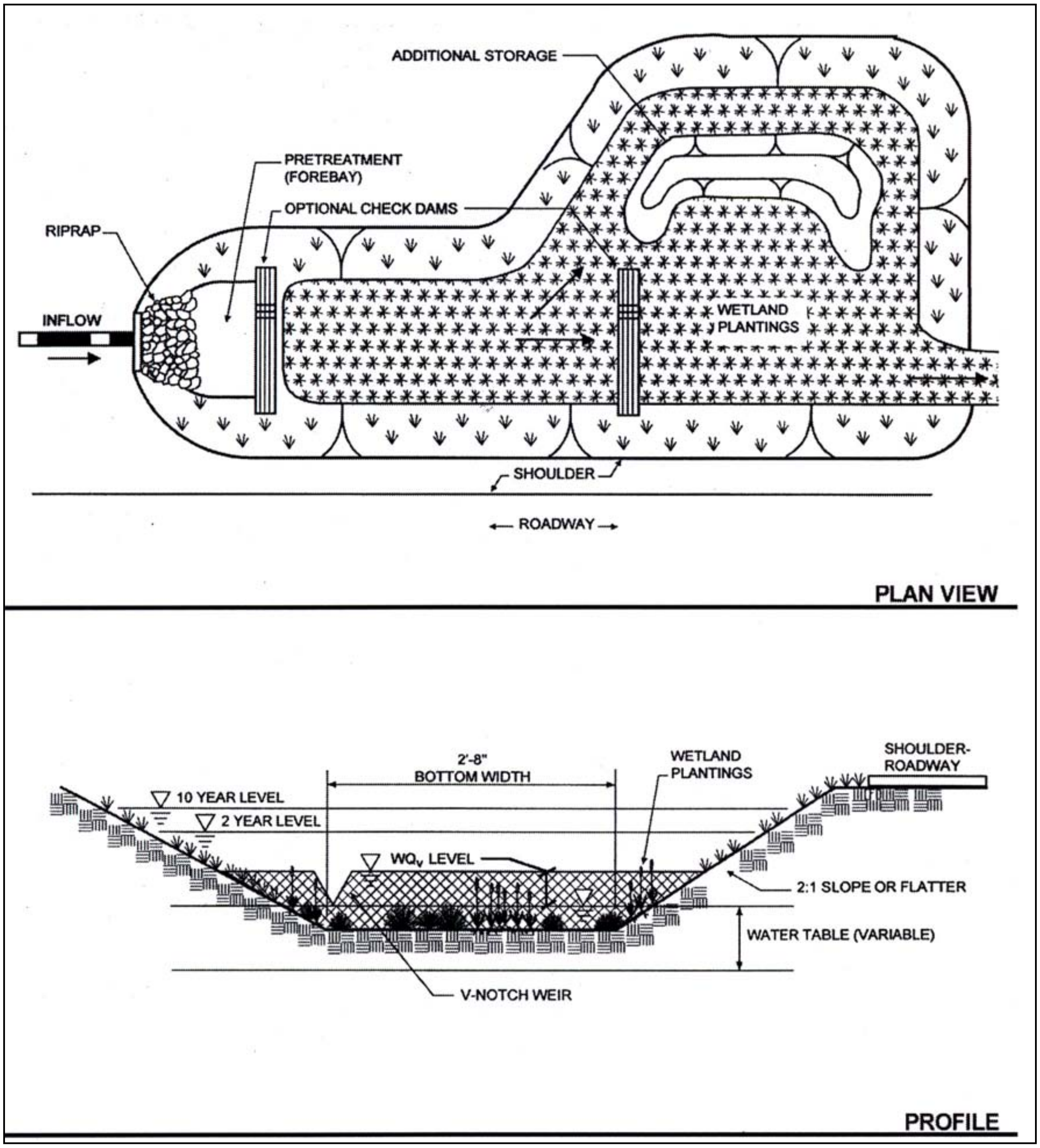

Figure E.25 Schematic of Wet Swale
(Source: Maryland Stormwater Design Manual, 2000)